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Mammalian Fauna and Biostratigraphy of the Upper Part of the Wind River Formation (Early to Middle Eocene), Natrona County, Wyoming, and the Wasatchian-Bridgerian Boundary

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MAMMALIAN FAUNA AND BIOSTRATIGRAPHY OF THE UPPER PART OF THE WIND RIVER FORMATION (EARLY TO MIDDLE EOCENE), NATRONA COUNTY, WYOMING, AND THE WASATCHIAN-BRIDGERIAN BOUNDARY

by

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Thesis directed by Associate Professor Judith A. Harris Van Couvering

The mammalian fauna of the Wind River Formation of the northeastern Wind River Basin, Wyoming, has been used to define the middle to late Wasatchian Land Mammal Age of western North America. Detailed stratigraphic studies of the upper part of the Wind River Formation and analysis of the mammalian fauna allow for the recognition of two valuable biostratigraphic zones, the *Lambdotherium* range zone and the *Palaeosyops borealis* assemblage zone. Approximately 120 mammalian species are known from these two zones. Stratigraphic data suggests that previous lithostratigraphic and biostratigraphic correlations of the Lost Cabin Member of the Wind River Formation are in error. Geologic structure of the Wind River Formation complicates correlations between exposures.

The *Lambdotherium* range zone is defined by the stratigraphic occurrence of *Lambdotherium popoagicum*. The *Palaeosyops borealis* assemblage zone is based on the first occurrence in the fossil record of *P. borealis*, *Trogosus*, *Hyrachyus* and *Antiacodon*. The Lostcabinian Land Mammal Subage of the Wasatchian is redefined on the basis of the *Lambdotherium* range zone of the Wind River Formation. The *Palaeosyops borealis* assemblage zone is included in the Gardnerbuttean Land Mammal Subage.

The recognition of these two zones in the upper part of the Wind River Formation and a review of late Wasatchian and early Bridgerian mammal faunas suggest that several alternatives can be used to define the Wasatchian-Bridgerian boundary throughout western North America. The first alternative defines the boundary at the first occurrence of Palaeosyops borealis, Trogosus, Hyrachyus and Antiacodon, or at the base of the Palaeosyops borealis assemblage zone. The second alternative places the boundary at the first occurrences of Isectolophus, Microsus, Sciuravus and Limnohyops, and last appearances of Esthonyx, Didymictis, Coryphodon and Bunophorus. It is believed that the Wasatchian-Bridgerian boundary is best defined by the first occurrences of P. borealis, Trogosus, Hyrachyus and Antiacodon, and thus that the Gardnerbuttean Land Mammal Subage be included in the Bridgerian.

The form and content of this abstract are approved. I recommend its publication.

Signed Judith Harris Va[illegible]
Faculty member in charge of thesis

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The primary and direct evidence in favor of evolution can be furnished only by paleontology. The geological record, so soon as it approaches completeness, must, when properly questioned, yield either an affirmative or a negative answer: if evolution has taken place, there will its mark be left; if it has not taken place, there will lie its refutation.

- Huxley

The nature of things unfolds itself in time.

- Cohen

This research is dedicated to the late 18th century social philosophers who laid the foundation for the ideas of change which so influence modern philosophy, theory, and research.

CHAPTER I

INTRODUCTION

Purpose

The purpose of this research is to clarify the lithostratigraphic and biostratigraphic relations of the upper part of the Wind River Formation in the northeastern Wind River Basin and to present a preliminary revision of its mammalian fauna. This contribution is made as part of a long term goal of developing a well-documented paleontological data set for the Wind River Formation to be used in recording the history of life and understanding the evolution and ecology of early Tertiary vertebrate faunas in the Wind River Basin (Stucky and Krishtalka, 1982).

Wind River Formation Faunas

The vertebrate fauna of the Wind River Formation of central Wyoming has long been used as the basis for defining and zoning the middle to late early Eocene (middle and late Wasatchian Land Mammal Age) mammalian faunas of western North America. From the first description of mammals from the Wind River Formation (Cope, 1880, 1881), researchers have recognized that the fauna was intermediate or transitional in composition between the greater part of the Wasatchian (early Eocene) and Bridgerian (middle Eocene). Both biostratigraphic (e.g. Osborn and Wortman, 1892; Osborn, 1909;

Granger, 1910; Sinclair and Granger, 1911; Osborn, 1929) and systematic studies (e.g. Osborn, 1902; Kitts, 1955; Radinsky, 1963; Gingerich and Simons, 1977) of Wind River mammals have documented the transitional nature of the Wind River Formation faunas. Two faunas associated with different lithologic units are generally recognized in the Wind River Formation: an older Lysite Member fauna (Guthrie, 1967) and a younger Lost Cabin member fauna (Guthrie, 1971), which have been used for defining, respectively, middle and late Wasatchian Land Mammal Age faunas. The Bridgerian character of the upper parts of the Wind River Formation (Tourtelot and Thompson, 1948) has been largely ignored.

Scope of Research

This study focuses on the geology and mammalian paleontology of the Red Creek-Deadman Butte area and type area of the Lost Cabin Member in the northeastern Wind River Basin (Fig. 1), areas which are critical in understanding the relations of the Wind River faunas. The mammalian fauna recovered from the Wind River Formation in this area is equivalent to the Lost Cabin Member fauna of others (Sinclair and Granger, 1911; Guthrie, 1971).

The principal results of this research are the documentation of the stratigraphic distribution of 120 mammalian species in the upper part of the Wind River Formation, and the recognition and mapping of a hitherto unrecognized volcanic unit which may be a Wagon Bed and/or Aycross Formation equivalent. Faunal lists of classic Lost Cabin Member fossil vertebrate localities are recorded

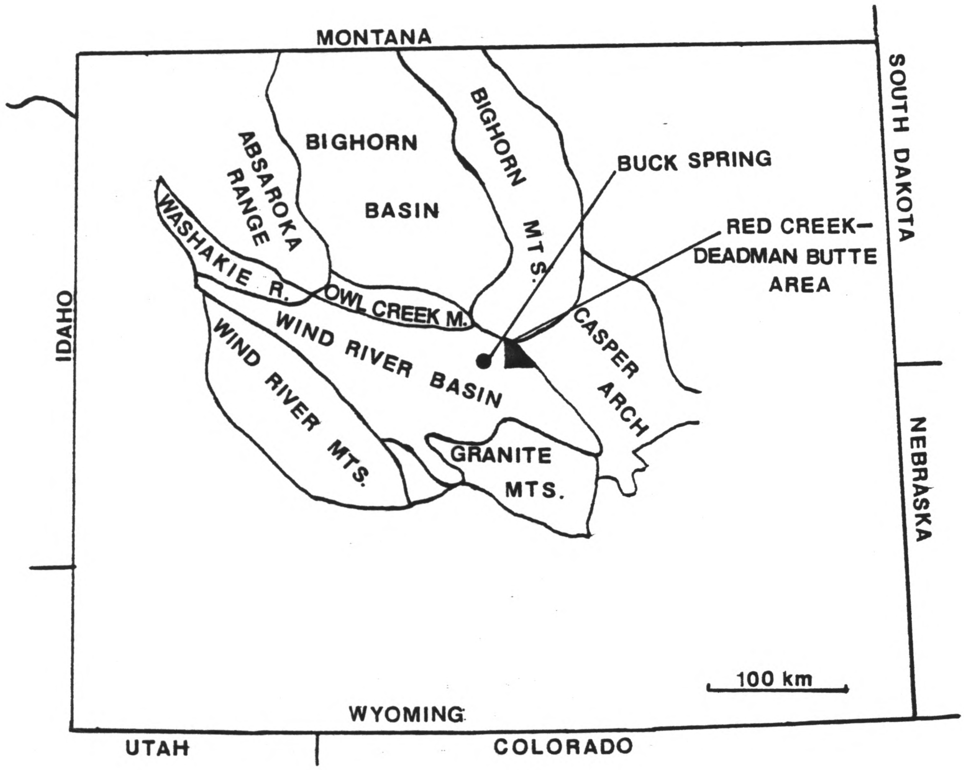

Fig. 1. Map of Wyoming showing major physiographic regions near the Wind River Basin and general location of the Red Creek-Deadman Butte and Buck Spring areas (after Seeland, 1978).

for the first time. The assumption that these localities occur within the same fossiliferous horizon or a narrow vertical interval of strata is shown to be false.

Two zones are recongized as valuable biostratigraphic markers in the upper part of the Wind River Formation: the Lambdotherium range zone and the Palaeosyops borealis assemblage zone. Use of these two zones clarifies the stratigraphic relations of fossil vertebrate localities in the Lost Cabin Member of the Wind River Formation. Recognition of these two zones also clarifies biostratigraphic relations with Eocene strata of similar age lying outside of the Wind River Basin, thus providing a more concrete basis for the definition of the Wasatchian-Bridgerian (early-middle Eocene) boundary in continental rocks throughout the western interior region of North America.

Abbreviations and Symbols

Mathematical symbols used in the text are those recommended by the Council of Biology Editors (1978). Abbreviations used in the text are: ACM, Amherst College Museum (Amherst); AMNH, American Museum of Natural History (New York); CM, Carnegie Museum of Natural History (Pittsburgh); DMNH, Denver Museum of Natural History (Denver); FMNH, Field Museum of Natural History (Chicago); JHU, Johns Hopkins University (Baltimore); MPM, Milwaukee Public Museum (Milwaukee); PU, Princeton University Museum (Princeton); TTU, Texas Tech University (Lubbock); UCB, University of California, Berkeley (Berkeley); UCM, University of Colorado Museum (Boulder); UMMP, University of Michigan Museum of Palaeontology (Ann Arbor);

USGSD, United States Geological Survey (Denver); USNM, United States National Museum (Washington); UW, The Geological Museum, University of Wyoming (Laramie); YPM, Yale Peabody Museum (New Haven); L, length greatest anteroposterior diameter of a tooth; W, width, greatest transverse diameter; Tr, trigonid; Ta, talonid; I, incisor; C, canine; P, premolar; M, molar. Tooth nomenclature is adapted from Van Valen (1966).

CHAPTER II

GEOLOGY OF THE WIND RIVER FORMATION, RED CREEK-DEADMAN BUTTE AREA

Introduction

The purpose of this chapter is to document the lithostratigraphy and structure of the Wind River Formation in the Red Creek-Deadman Butte and Buck Spring areas of the northeastern Wind River Basin as a necessary background to a biostratigraphic zonation of the upper part of the Wind River Formation (Fig. 1, Plates I and II). Lithology and biostratigraphy are separate and distinct features of the geologic record; spurious lithologic correlations, when not based on detailed stratigraphic field studies, often confuse biostratigraphic relations. The biostratigraphic zonation presented in Chapter III is based on detailed stratigraphic sections coupled with detailed horizon by horizon fossil assignment and collection.

The first part of this chapter is concerned with the geologic structures within the Wind River Formation. Faulting and folding of Wind River strata is common in most exposures. Each area of exposure is discussed to emphasize the lithologic complexity of the Wind River Formation. These data are used to discuss the possible lithostratigraphic correlations and depositional environments.

Geographical and Geological Setting

The Wind River Basin in central Wyoming is a large trapezoidal depression encompassing approximately 8,500 square miles of land surface area (Fig. 1). It is bounded on the north by the Bighorn and Owl Creek Mountains, on the northwest by the Washakie Range, on the west by the Wind River Mountains, on the south by the Granite Mountains and Rattlesnake Hills and on the east by the Casper Arch. The western two-thirds of the basin are drained to the north by Wind River into the Bighorn Basin, and the eastern third is drained to the east by the Powder and North Platte Rivers. Tributaries of these rivers with headwaters in the mountains surrounding the basin have cut through and exposed Tertiary and older sediments throughout the basin.

Nace (1936), Tourtelot (1948), Keefer (1965a) and Soister (1968) have outlined the history of investigations of the geology of the Wind River Formation and Wind River Basin. Keefer (1965a) has provided excellent summaries of pre-Wind River Formation strata and the general geologic history of the Wind River Basin since the Cretaceous. Seeland (1978) presents a depositional model for the Wind River Formation.

The general geologic history of the northeastern Wind River Basin has been detailed by Tourtelot (1953) and Woodward (1957). The most recent geologic maps of the area were prepared by Keefer (1970) and Love et al. (1978). The most important discussions of Wind River Formation geology in the northeastern corner of the basin are those of Tourtelot (1948) and Love (1978). Preliminary observations on the area of this report were provided by Stucky and Krishtalka (1982). The following geologic summary is taken from their work.

During Laramide orogeny, from late Cretaceous through early Eocene time, the highland and mountain areas were uplifted to form the Wind River Basin. Consequent basin subsidence and faulting near the basin margin resulted in stratal displacements of as much as 30,000 ft. (9,100 m) (Keefer, 1965a). The basin floor, however, remained at a relatively constant elevation of not more than a few thousand feet (Keefer, 1965a). Erosion of mountain and highland areas resulted in the deposition of alluvial fan and braidplain deposits around the basin margin, and lacustrine, stream channel and overbank deposits in the basin interior (Keefer, 1965a; Korth, 1982; this report). The Paleo-Wind River developed and drained the Wind River Basin to the east (Seeland, 1978). After the early Eocene, aggradation continued until many mountainous areas were covered with volcaniclastic and terrigenous clastic debris (Love, 1978). Beginning in the Pleistocene the mountains were exhumed by erosion, revealing the paleolandscape of the early Eocene. The modern landscape reflects the topographic complexity of the early and middle Eocene during the time the Wind River Formation was deposited (Woodward, 1957).

Tectonic, erosional and depositional events varied from place to place throughout the Wind River Basin (Keefer, 1965a, 1970). Love (1978) outlined these events in the Badwater area just to the east of the Red Creek-Deadman Butte area. He records seven depositional and six tectonic events in the Badwater area during the

Cenezoic. This is presented here for a general summary and clarification for the reader (Table I).

The Red Creek-Deadman Butte area illustrates the variability in these events when compared to the Badwater area. At the same time that the Bighorn Mountains were being uplifted and alluvial fans were being deposited in the Badwater area, braidplains were deposited near the southern Bighorn Mountain front in the Red Creek-Deadman Butte area, where relatively little tectonic activity was occurring.

Fieldwork

Fieldwork was conducted primarily during the summers of 1980 and 1981. Standard geologic techniques were used. Stratigraphic sections were measured by Jacob's staff and Brunton compass. Plane table mapping in areas of low topographic relief insured correct correlations between key marker beds. Hand specimens of sediments were collected from many lithostratigraphic horizons and are on file in the UCM collections. Many key fossiliferous horizons were sampled by surface prospect and screen washing. Attitudes of strata were estimated or measured by Brunton compass. Geologic mapping was traced on the Arminto, Badwater SE and Waltman NW 7½' quadrangles using both previously documented formation boundaries (Keefer, 1965a, 1970; Love et al., 1978) and field observations.

Structural Geology--Wind River Formation

Geologic studies of the Wind River Formation in the Red Creek-Deadman Butte area have focused primarily on the major geologic structures. These structures have been well documented by

Table 1. Cenozoic tectonic and depositional events in the Badwater area of the Wind River Basin, Wyoming (after Love, 1978).

Depositional Event 1. Deposition of the Paleocene Fort Union Formation.

Tectonic Event 1. Moderate uplift of the southern Bighorn Mountains during the deposition of the Paleocene Fort Union Formation.

Tectonic Event 2. Abrupt uplift and southward thrust of the southern Bighorn Mountains. "Paleocene and older strata were overturned" (Love, 1978, p. 236).

Depositional Event 2. Paleozoic and younger strata were stripped, in part, from highland areas and deposited as the earliest Eocene Indian Meadows Formation.

Tectonic Event 3. Uplift again occurred in the southern Bighorn Mountains. Indian Meadows Formation tilted southwestward to as much as 35 degrees.

Depositional Event 3. Paleozoic stripped from highland areas and deposited as the Lysite Member of the Wind River Formation.

Tectonic Event 4. Uplift occurred in the southern Bighorn Mountains and along the western limb of the Casper Arch resulting in moderate tilting of the Lysite and older strata.

Depositional Event 4. Erosion of southern Bighorn Mountains down to the Precambrian core and deposition of the Lost Cabin Member of the Wind River Formation.

Tectonic Event 5. Cedar Ridge fault system developed with offset of as much as 25,000 ft.

Depositional Event 5. Deposition of volcaniclastic and terrigenous clastic middle to late Eocene deposits.

Depositional Event 6. Deposition of the airborne and reworked volcaniclastic White River Formation, partially covering the Bighorn Mountains during the Oligocene.

Depositional Event 7. Deposition of Miocene tuffaceous sandstones resulting in the burial of the Bighorn and Owl Creek Mountains.

Tectonic Event 6. Southern end of Bighorn Mountains hinged down southward along the Cedar Ridge Fault. Probable minor faulting and folding in Wind River Formation occurred at this time.

Tourtelot (1948, 1953), Woodward (1957), Gard (1969), Keefer (1970) and Love (1978). Few researchers have, however, documented structural features within the Wind River Formation.

In practically all exposures of the Wind River Formation, minor faulting and changes in dip occur, making correlation difficult even in continuous exposures (Plate I). Correlation of exposures separated by covered sections is extremely difficult and often unwarranted unless nearly identical lithostratigraphic sets of strata occur. Reliability of lithostratigraphic correlation decreases substantially as the distance between exposures increases because of potential intervening but unknown geologic structure and lateral variation in lithology. Any biostratigraphic relations proposed on the basis of attitudinal and elevational relations without lithostratigraphic control should be viewed cautiously.

General Structure

Attitudes of Wind River Formation strata are structurally determined by their proximity to uplifted strata of the southern Bighorn Mountains and Casper Arch and to the Dry Fork and Cedar Ridge Faults. Compared to the structural relations of Wind River strata in the Badwater area (Love, 1978), structural relations in the Red Creek-Deadman Butte area are less complex (Tourtelot, 1953; Woodward, 1957).

Wind River strata along the southern flank of the Bighorn Mountains strike east-west and dip between 6 and 8 degrees South. In this area the Wind River Formation lies with angular unconformity of approximately 10 degrees on Mesozoic strata. Occasional small wedges of Mesozoic strata are completely surrounded by sediments of the Wind River Formation in the central portion of T. 38 N., R. 87 W., suggesting an erosional surface of considerable relief between the Wind River Formation and underlying Mesozoic strata (Tourtelot, 1953; Woodward, 1957). North and west of Arminto in Secs. 2 and 12, T. 37 N., R. 86 W., Wind River Formation strata strike north-south and dip at approximately 6 degrees West. Further to the south on the western limb of the Casper Arch in the SE ¼ of T. 37 N., R. 87 W., E ½ of Sec. 1, T. 36 N., R. 87 W., and NW ¼ of T. 36 N., R. 86 W., fairly extensive exposures of the Wind River Formation lie with approximately 45 degrees angular unconformity on the Paleocene Fort Union Formation and dip to the west at 45 degrees. These attitudinal relationships of Wind River strata in the Red Creek-Deadman Butte area suggest a broad synclinal fold with a northeast trend that folds down to the south toward the basin axis (see Keefer, 1965a).

Cedar Ridge Fault

Tourtelot (1953) has mapped the Cedar Ridge Fault in the Badwater Creek area. This fault extends from the southern part of the Owl Creek Mountains eastward to the eastern part of Cedar Ridge in Secs. 4 and 5, T. 38 N., R. 88 W.

A possible continuation of the Cedar Ridge Fault was mapped in Sec. 25, T. 38 N., R. 88 W., and Sec. 30, T. 38 N., R. 87 W. (see Plate I). This continuation has greater than 80 ft. (24 m) or more of displacement. This is suggested by the fault contact of the Wind River Formation and the Middle (?) Eocene volcaniclastic sequence (see end of this chapter). Areas between the easternmost mapped extent of the Cedar Ridge Fault and this fault are grass covered, making direct relations between the two faults impossible to determine without subsurface data. A continuation of the trends of both the Cedar Ridge Fault to the southeast and this fault to the northeast suggests that they are the same.

Dry Fork Fault

The Dry Fork Fault has been fully mapped in the Red Creek-Deadman Butte area by Woodward (1957). Minor normal faults of less than 25 ft. (8 m) displacement trend parallel to Dry Fork Fault, suggesting some structural relationship. These minor faults were recognized in the NW ¼, SW ¼ of Sec. 17, N ¼ of Sec. 19, S ½ of Secs. 19 and 20, N ½ of Sec. 30, S ½ of Sec. 22 and S ½ of Secs. 27 and 28 of T. 38 N., R. 87 W. (Plate I). The downthrown side is to the north of each of these faults. Displacement of each fault is easily determined in outcrop and can be accounted for in measured sections.

Other Faults

1) A normal fault of indeterminate displacement was mapped in the S ½ of Sec. 27, T. 38 N., R. 87 W. To the north, on the upthrown side of the fault, variegated sediments of the Lost Cabin Member of the Wind River Formation were exposed; to the south, gray mudstones and sandstones were exposed. The Palaeosyops jaw locality (UCM Loc. 81010) was found just to the south of the fault and cannot be directly placed in the Deadman Butte stratigraphic section.

2) Biostratigraphic relations between the Davis Ranch and Wolton localities (Locs. 1 and 2, respectively, of Guthrie, 1971)

suggest that faults may be present in the vicinity of Alkali Creek in T. 37 N., R. 87 W. Wind River strata at Davis Ranch dip to the south at approximately 4 degrees. Although both localities are at nearly the same elevation (6,000-6,200 ft.), the fauna at the Wolton locality is within the older Lambdotherium zone, whereas the fauna at Davis Ranch is used to define the younger Palaeosyops borealis zone. If no faults occurred in this area, trigonometric calculation indicates that the Wolton locality should be at least several hundred feet above Davis Ranch (see Korth, 1982), and thus is younger than Davis Ranch, contradicting the faunal evidence. In addition, the nearly straight course of Alkali Creek and subsurface data suggest a fault controlled valley (J. D. Love, verbal communication to P. Robinson, 1982).

3) On the northern side of the exposures at the Buck Spring locality (Locality 3 of Guthrie, 1971; probable type area of the Lost Cabin Member, see Tourtelot, 1948), strata of the Lost Cabin Member are folded into a monocline with the limb of the monocline dipping to the north at approximately 12 degrees. In the next set of exposures to the north of this area, strata are flat lying, suggesting that unmapped faults may have confused lithostratigraphic correlation in the Badwater Creek area as well.

Summary

Attitudes of the Wind River Formation suggest a synclinal fold between the southern Bighorn Mountains and western limb of the Casper Arch. A possible continuation of the Cedar Ridge Fault and other faults are present in the Red Creek-Deadman Butte area.

The structure of the Wind River Formation prevents horizon to horizon correlations between exposures.

Lithostratigraphy

Wind River Formation

The Wind River Formation was first called the "Wind River Valley deposits" by Meek and Hayden (1861), who believed they were developed between the early Tertiary "lignite deposits" (=Paleocene Fort Union Formation) and the Oligocene "White River Tertiary Deposits." In 1878, Hayden suggested that these deposits represented the Wasatch group of southwestern Wyoming. Two years later, Jacob L. Wortman discovered fossil mammals in the Wind River Formation which indicated that these deposits were intermediate in age between the Wasatch and Bridger beds (Cope, 1880, 1881).

Granger (1910) and Sinclair and Granger (1911) named the Lysite and Lost Cabin formations (=members) of the Wind River group (=formation) in the Badwater Creek area of the northeastern Wind River Basin. In 1948, Tourtelot lowered the rank of the Lysite and Lost Cabin to member and emended the criteria of Sinclair and Granger for recognizing them. Keefer (1965a, 1965b, and 1970) reviewed the geology of the Wind River Basin and discussed the Wind River Formation in detail. In 1968, Soister described a unit exposed in the south central part of the Wind River Basin as the Puddle Springs Arkose Member of the Wind River Formation.

In a broad sense, the Wind River Formation is divisible into two facies, a mountainward and basinward facies (Keefer, 1965a).

Sediments of the mountainward facies, typified by the Lysite Member (Sinclair and Granger, 1911; Tourtelot, 1948; Keefer, 1965a; Korth, 1982), consist of pebble to boulder conglomerates, large scale wedge-shaped tabular sandstones and mudstones. These are formed of clastic sediments derived from the erosion of Precambrian, Paleozoic and Mesozoic strata in highland areas.

The basinward facies of the Wind River Formation, typified by the major exposures of the Lost Cabin Member, occupies a major part of the interior of the Wind River Basin. Sediments of this basinward facies consist primarily of tabular mudstones and channel sandstones. In some areas carbonaceous shales and lignite beds are common (cf., Soister, 1968). In the area of this report, both mountainward and basinward facies are developed.

Clarification of Wind River Formation Stratigraphic Terminology

Significant confusion has resulted from the use of similar terms for stratigraphic units and faunas in the Wind River Formation and from the application of these terms to deposits outside of the Wind River Basin. The unfortunate result has been the *a priori* assumption that the age and identification of a fossil assemblage within the Wind River Formation is determined by the lithologic unit in which it is preserved. This assumption is clearly false; similar lithologies simply suggest similar depositional and diagenetic conditions. Because the Wind River Formation has been used as the basis for defining the middle to late Wasatchian Land Mammal Age (Lysitean and Lostcabinian) in western North America (see e.g., Wood et al., 1941; Gazin, 1952, 1962; Robinson, 1966; Guthrie, 1967, 1971; Bown, 1979; Schankler, 1980), age relations of "late Wasatchian" faunas have been obscured by a lack of a rigorous use of terms.

Table 2 clarifies the terminology used for the Wind River Formation and its faunas. Abbreviated forms of these terms other than those indicated are not recommended.

Lithology

The Wind River Formation in the area of this report is divided into a Lower Gray Member and the Lost Cabin Member (Plate I). The Lower Gray Member represents a mappable lighologic unit of homogeneous lithology exposed only along the northern portion of the Red Creek-Deadman Butte area to the south of the exposures of Mesozoic strata in T. 38 N., R. 87 W. The Lost Cabin Member occupies most of the rest of the area of this report. The characteristic lithology and depositional environments of these two members are discussed at the end of this section.

The Lost Cabin Member has long been recognized for its widely diverse and interesting vertebrate fauna. Vertebrate paleontologists have suggested that the fauna was recovered from a narrow interval of strata (Granger, 1910; Guthrie, 1971). This generalization was based primarily on the assumption that prominent marker beds in exposures separated by some 20 miles (32 km) were the same fossiliferous horizon (Granger, 1910).

The lithologic descriptions presented here and the stratigraphic sections (correlated in Plate II; Appendix A) provide

Table 2. Terminology used in this report for rocks and faunas of the Wind River Formation. Abbreviations are in parentheses.

FORMAL LITHOSTRATIGRAPHIC UNITS

Lysite Member.- Lithostratigraphic unit of member rank of the Wind River Formation as defined and mapped by Tourtelot (1948, 1953).

Lost Cabin Member.- Lithostratigraphic unit of member rank of the Wind River Formation as defined and mapped by Tourtelot (1948, 1953) and emended by Keefer (1965a).

Wind River Formation.- Lithostratigraphic unit of formation rank limited to the Wind River Basin as characterized by Keefer (1965a).

INFORMAL LITHOSTRATIGRAPHIC UNIT

Lower Gray Member.- Mappable lithostratigraphic unit of the Wind River Formation exposed in central part of T. 38 N., R. 87 W. (see Plate I).

BIOSTRATIGRAPHIC UNITS (UPPER PART OF WIND RIVER FORMATION ONLY)

Lambdotherium range zone (*Lambdotherium* zone).- Biostratigraphic unit of the Wind River Formation defined on the basis of the stratigraphic occurrence of *Lambdotherium popoagicum* in the Red Creek, Deadman Butte and Buck Spring stratigraphic sections. The *Lambdotherium* range zone is fully discussed in Chapter III.

Palaeosyops borealis assemblage zone (*Palaeosyops borealis* zone).- Biostratigraphic unit of the Wind River Formation defined on the basis of the stratigraphic occurrence of *Palaeosyops borealis*, *Trogosus* sp., *Hyrachyus* sp., cf. *H. eximius*, *Microsyops lundeliusi* and *Antiacodon* in the Red Creek, Deadman Butte, Buck Spring and Davis Ranch stratigraphic sections. The *Palaeosyops borealis* assemblage zone is fully discussed in Chapter III.

Table 2 (continued). Terminology used in this report for rocks and faunas of the Wind River Formation. Abbreviations are in parentheses.

INFORMAL BIOCHRONOLOGIC UNITS

<u>Lysitean Land Mammal Subage</u> (Lysitean).- Informal biochronologic Land Mammal Subage which denotes the middle Wasatchian Land Mammal Age for faunas in western North America. Defined on the basis of the Lysite Member fauna, exclusive of the occurrence of *Lambdotherium* (Guthrie, 1967). Korth (1981) has listed several rodent species of value in determining the Lysitean.

<u>Lostcabinian Land Mammal Subage</u> (Lostcabinian).- Informal biochronologic Land Mammal Subage which denotes the late Wasatchian Land Mammal Age in western North America. Defined originally on the basis of the Lost Cabin Member fauna. In this report the Lostcabinian Land Mammal Subage is defined on the basis of the occurrence of *Lambdotherium* in an assemblage.

<u>Gardnerbuttean Land Mammal Subage</u> (Gardnerbuttean).- Informal biochronologic Land Mammal Subage which tentatively denotes early Bridgerian in western North America. Defined on the basis of the upper Huerfano Formation fauna of the Huerfano Basin (Robinson, 1966). As used in this report the Gardnerbuttean is also defined by localities in the Huerfano Basin and elsewhere from which *Palaeosyops borealis* is known.

<u>Wasatchian Land Mammal Age</u> (Wasatchian).- Informal biochronologic Land Mammal Age in western North America, defined by the first occurrence in the fossil record of Perissodactyla, Artiodactyla, Adapidae (=Notharctidae) and Hyaenodontidae (Rose, 1981) at its lower boundary and the first occurrence, tentatively, of Brontotheriidae, Trogosinae and *Hyrachyus* above its upper boundary; early Eocene.

<u>Bridgerian Land Mammal Age</u> (Bridgerian).- Informal biochronologic Land Mammal Age in western North America, defined by the first occurrence, tentatively, of Brontotheriidae, Trogosinae and *Hyrachyus* at its lower boundary and the first occurrence of Lagomorpha, Agriochoeridae and Merycoidodontidae above its upper boundary (West et al., in press); middle Eocene.

evidence rejecting the supposed correlation of two key fossiliferous horizons--the "dark red stratum" (Granger, 1910) or "maroon shale" layers (Guthrie, 1971) at Davis Ranch and Buck Spring.

The Lost Cabin Member exhibits different lithologies from exposure to exposure, and correlation from area to area is often impossible. As aptly pointed out by Soister (p. A9, 1968), lateral and vertical lithologic variation of the Wind River Formation is "so pronounced that composite stratigraphic sections, when applied to large areas, can give a false picture of the formation." His observations are especially pertinent to the Lost Cabin Member. For this reason each major area of exposure of the Wind River Formation is discussed separately to clarify the local lithostratigraphic sequences and to point out vertical and horizontal variations in lithology as they apply to biostratigraphy (Figs. 2 and 3). While this is not conventional practice, it is done here to emphasize that although lithologies may be quite similar in different areas, they are not necessarily correlates. The assumption that they do indeed represent the same horizon has confused the biostratigraphic relations of the Lost Cabin Member faunas (Chapter III).

<u>Red Creek Stratigraphic Section</u> (Plate II; Appendix A)--The Red Creek stratigraphic section (Fig. 3, Appendix A) was measured from the contact of the Wind River Formation with Mesozoic strata in Sec. 17, T. 38 N., R. 87 W., to the contact with an overlying volcaniclastic sequence in the SE ¼, Sec. 25, T. 38 N., R. 88 W. Total thickness of the Wind River Formation in the Red Creek section varies from a wedge edge at the unconformable contact on the Mesozoic strata to several thousand feet in the subsurface (Keefer, 1965a).

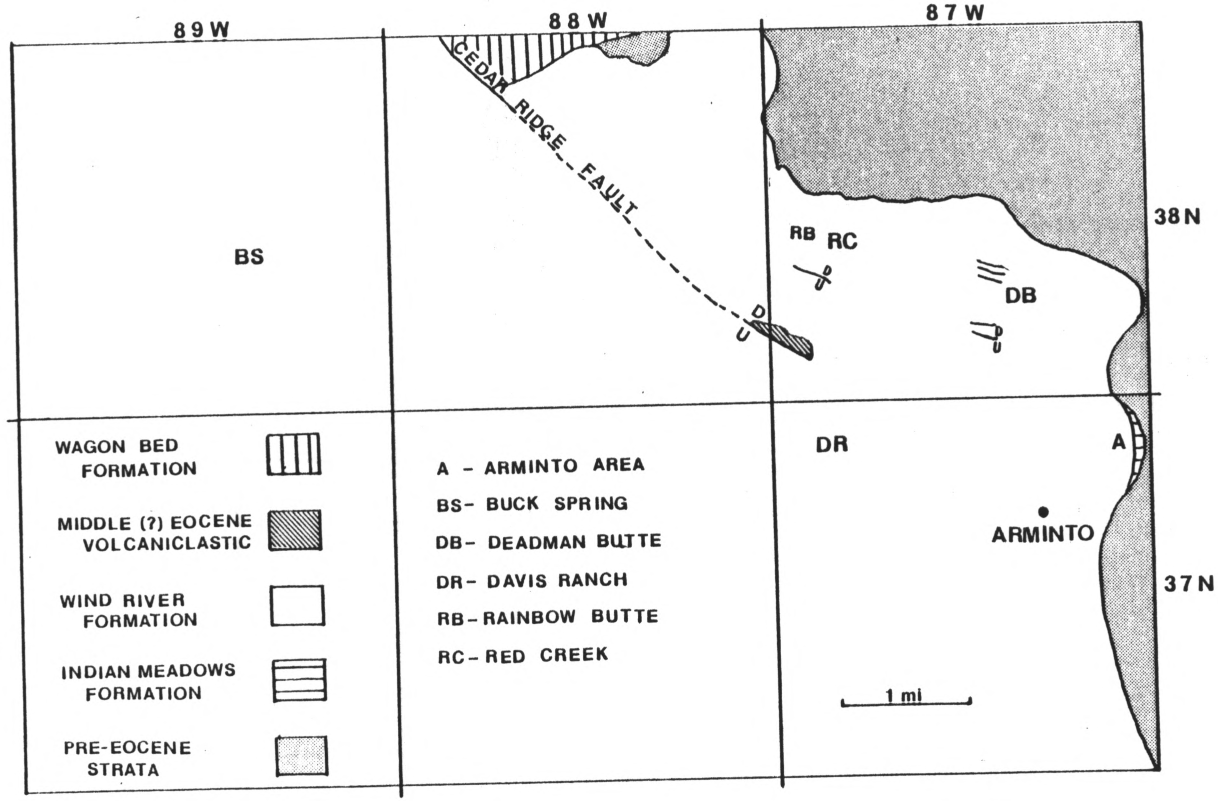

Fig. 2. Geologic map of Eocene strata and principal areas of exposure discussed in the text (after Keefer, 1970).

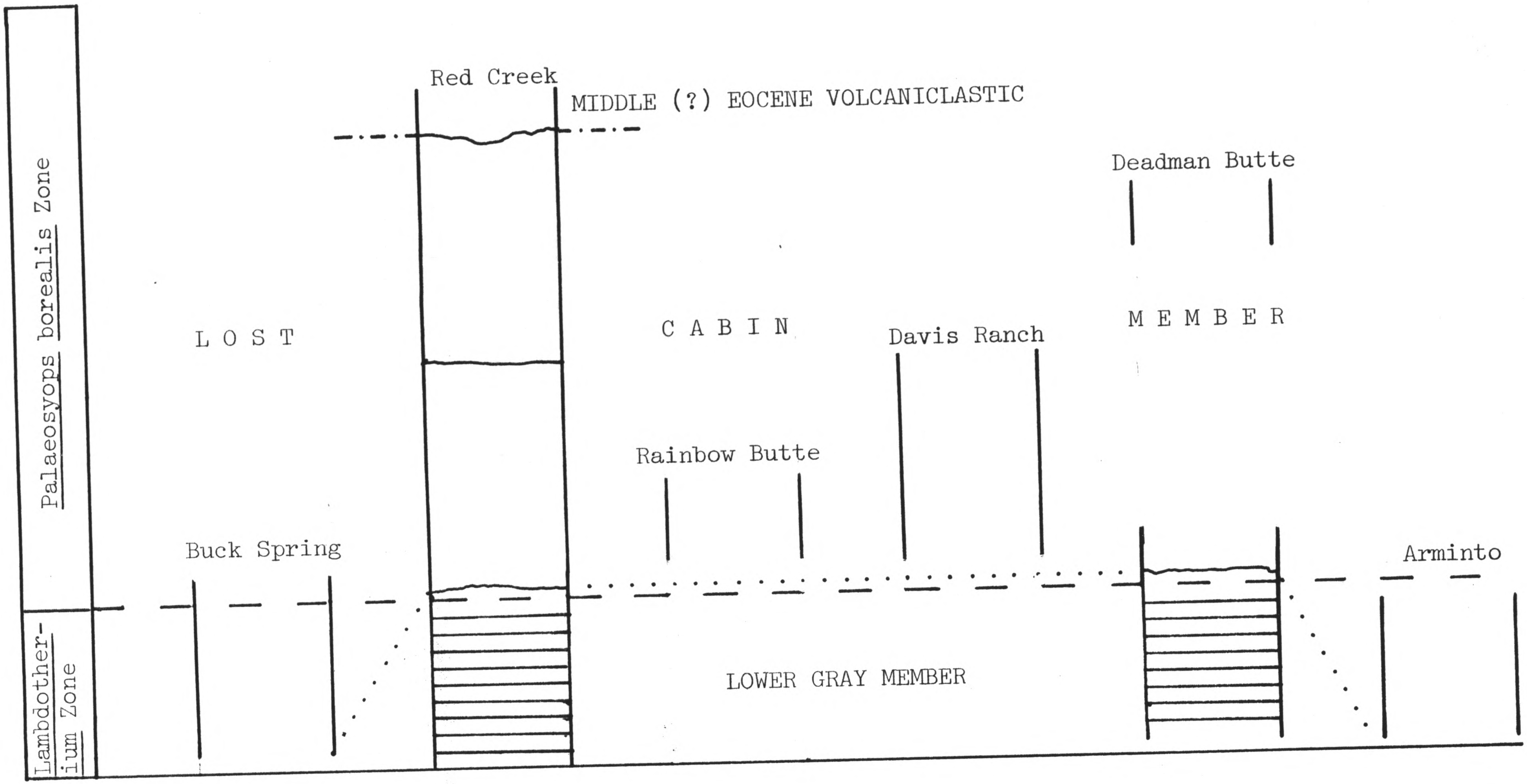

Fig. 3. Generalized lithostratigraphic and biostratigraphic correlation of the Red Creek-Deadman Butte and Buck Spring areas. Note that the Lost Cabin Member of the Wind River Formation is time transgressive. See Fig. 2 for the general location of the stratigraphic columns.

Measured thickness in surface outcrop is 655 ft. (200 m). Three lithologic units are recognized in the Red Creek stratigraphic section: 1) a lower gray sequence; 2) a variegated sequence; and 3) an upper gray sequence. The lower gray sequence is equivalent to the Lower Gray Member while the latter two sequences are assigned to the Lost Cabin Member.

The lower gray sequence is a maximum of 131.5 ft. (40 m) thick (Fig. 4). The sequence is characterized by tabular grayish green tuffaceous sandstones and mudstones, with occasional tabular dark grayish green claystones and lenticular carbonaceous shales. Conglomerates are of local importance and occur as lenticular units within sandstones.

Sandstones make up 58 percent of the lower gray sequence and vary between 2.0 (0.6 m) and 31.0 (9.5 m) ft. in thickness. Most sandstones are quartz arenites and have a tabular geometry. Sandstones may be followed in outcrop for up to several kilometers. The sand particles are predominantly well rounded, fine to medium, quartz grains probably derived from sandstones of the Cloverly and Morrison Formations. Isolated bones and teeth of fossil vertebrates are found in some sandstones (UCM Loc. 79045). Conglomeratic beds are clast supported and occur as lenses within sandstone units (Fig. 5). The matrix of these conglomerates is a well sorted fine to medium sand. Clasts in conglomerates consist of angular to rounded fragments of sandstones, limestones and chert, derived from primarily Mesozoic formations exposed just to the north of the study area. Rounded fragments of the belemnite Pachyteuthis, derived from the Sundance Formation (Jurassic), are occasionally found in

Fig. 4. Exposure of Lower Gray Member of the Wind River Formation, NW ¼, Sec. 17, T. 38 N., R. 87 W.

Fig. 5. Conglomeratic lense in sandstone of Lower Gray Member, SW¼ Sec. 17, T. 38 N., R. 87 W. Camera lense cap is approximately 5 cm in diameter.

conglomerates. Within a single sandstone unit, as many as eight lenticular conglomeratic lenses separated by sandstone matrix were recorded in a thickness of 31 ft. (9 m). These lenses varied from 0.66 ft. (0.2 m) to 2.0 ft. (0.6 m) in thickness and 2.0 ft. (0.6 m) to 8.0 ft. (2.4 m) in lateral extent. Boundaries between sandstones and conglomerates are sharp, as are boundaries of sandstones on mudstones.

Gray, probably tuffaceous mudstones represent 38 percent of the lower gray sequence. Mudstones vary between 0.5 ft. (0.2 m) and 4.0 ft. (1.2 m) in thickness. Most mudstones are siltstones with a very low percentage of sand and a high percentage of clay. Pedotubules, calcareous glaebules, coprolites and articulated fossil vertebrates occur in association in some gray mudstones which generally have a bluish-gray cast when seen from a long distance (UCM Loc. 79039). Some mudstone units contain abundant gypsum crystals and occasional petrified wood and invertebrate shell fragments.

Dark grayish green claystones and carbonaceous shales are a minor constituent of the lower gray sequence in the Red Creek section, comprising 4 percent of the sequence thickness. Claystones vary from 0.5 ft. (0.2 m) to 3.0 ft. (0.9 m) in thickness but are laterally quite extensive. One claystone unit was mapped for one kilometer (unit 15, Red Creek section, Appendix A). This unit was easily recognized in outcrop by its dark gray color band and proved to be useful in correlation. Claystones are thinly laminated and preserve occasional burrows approximately 3 to 4 mm in diameter. Both color and lithologic contacts with lower and upper units are sharp; occasional intraclasts of these claystones are incorporated into overlying units.

Carbonaceous shales weather dark brown. Leaf and stem fragments occur locally. Carbonaceous shales are lenticular in overall morphology. No fossil vertebrates are known from either the claystones or carbonaceous shales in this lower gray sequence.

The variegated sequence lies conformably on the lower gray sequence in the Red Creek section. Thickness is 176.5 ft. (53.8 m). The lower boundary of the variegated sequence is defined as the lowest sandstone unit which contains abundant rock fragments and calcareous cement. This boundary coincides with the lower boundary of the Lost Cabin Member (see Tourtelot, 1948; Korth, 1982). The variegated sequence is characterized by channel sandstones and alternating mottled red-gray and gray mudstones. Claystones are rare and carbonaceous shales do not occur.

Sandstones represent 47 percent of the variegated sequence. These sandstones have apron-channel, shoestring channel and tabular geometries (see Bown, 1979). Shoestring channel sandstones are prominent linear features on the landscape surface. Most sandstones are crossbedded and have a calcium carbonate cement. Calcareous, preferentially-cemented, cannonball concretions up to one foot in diameter are common in some sandstone units. Grains are generally subrounded, very fine to coarse, quartz and rock fragments. Pebble conglomerates are rare but occur at the base of some sandstones. Pebbles in the conglomerates are derived from Precambrian sources.

Alternating mottled red-gray and gray mudstones make up 48 percent of the variegated sequence. Mottled red-gray mudstones often contain calcareous pedotubules and glaebules, coprolites, eggshell fragments and fossil vertebrates in abundance (UCM Loc. 79040). Gray mudstones may contain these as well (UCM Loc. 80061) but are generally not bioturbated and not fossiliferous. Mudstones generally do not show primary structure in hand samples. This variegated sequence represents a basinward facies of the Wind River Formation.

The <u>upper gray sequence</u> lies conformably on the variegated sequence and represents the upper part of the Lost Cabin Member. The lower boundary of the upper gray sequence is arbitrarily defined at the conformable base of a gray mudstone that lies on the uppermost mottled red-gray mudstone in the variegated sequence. This unit is conformably overlain by a volcaniclastic sequence which is inferred to represent a Wagon Bed or Aycross Formation equivalent. The upper gray sequence is characterized by thick crossbedded sandstones, gray mudstones and dark gray claystones which contrast with the alternating red and gray bands of the variegated sequence. Thickness is 334 ft. (101.8 m).

Sandstone units in the upper gray sequence vary between 4 ft. (1.2 m) and 82 ft. (25 m) in thickness and represent 46 percent of the total thickness of the sequence. These sandstones are crossbedded, micaceous, and have a calcareous cement. Preferentially cemented calcareous cannonball concretions are common. The thickest sandstone in this sequence contains carbonaceous shale plugs and silicified fossil logs. The sand grains are medium to coarse quartz and rock fragments. Conglomeratic lenses occasionally occur at the base of sandstones and are composed primarily of pebble-sized, rounded, Precambrian rock fragments.

Gray mudstones represent 53 percent of the upper gray sequence. These mudstones have sharp color and lithologic contacts with adjacent units and generally show graded bedding. Bioturbation structures are uncommon or absent. Many of these mudstones are channeled into underlying units and often have mudstone, calcareous glaebule and claystone intraclasts at their base. Many contain biotite (?) flakes which decrease in size toward the top of the unit. All mudstones are micaceous and are probably tuffaceous. A roadcut in Sec. 19, 38 N., R. 87 W. best exhibits mudstones and claystones of the upper gray sequence.

Dark gray claystones nearly identical in structure to dark gray claystones in the lower gray sequence are important marker beds. These units are laterally persistent and vary between 2 ft. (0.6 m) and 3 ft. (0.9 m) in thickness. Dark gray claystones are thinly laminated and have sharp contacts with adjacent units. As is true for dark gray claystones in the lower gray sequence, these claystones often have burrows that are filled with sediment similar to that found in the overlying unit.

Fossil vertebrates are extremely rare in the upper gray sequence of the Red Creek section, being represented only by several lepisosteid scales and turtle shell fragments.

<u>Deadman Butte Stratigraphic Section</u> (Plate II; Appendix A)--The Deadman Butte stratigraphic section was measured in Sec. 22, T. 38 N., R. 87 W. The unit lies unconformably on Mesozoic strata

(Tourtelot, 1953). The top of the Wind River Formation is not preserved in this area. Measured thickness of the Wind River Formation is 160 ft. (48.8 m) in this section.

A lower gray sequence assigned to the Lower Gray Member and a variegated sequence of the Lost Cabin Member were measured in this stratigraphic section. These closely resemble the lower gray and variegated sequences of the Red Creek stratigraphic section (Fig. 6). In addition, a sequence of gray mudstones and sandstones that outcrop south of the fault in the S ½ of Sec. 27, T. 38 N., R. 87 W. probably represent sediments which correlate with the upper gray sequence of the Red Creek section.

The lower gray sequence in the Deadman Butte section is 142 ft. (43.3 m) in thickness. The sequence is characterized by thick tabular sandstones and tabular dark gray claystones and mudstones. Sandstones are as described for the lower gray sequence in the Red Creek section, although some are extremely fossiliferous--Deadman Butte and *Viverravus* localities (UCM Loc. 80062 and UCM Loc. 81008, respectively; Stucky and Krishtalka, 1982). Isolated teeth and limb elements of vertebrates are extremely common in these fossiliferous horizons.

Dark gray claystones and gray mudstones are similar to those described for the lower gray sequence of the Red Creek section. Carbonaceous shales are more common in this sequence than in the Red Creek section.

The variegated sequence of the Lost Cabin Member in the Deadman Butte section is truncated by faulting and surface erosion. The lithological change from the lower gray to the variegated

Fig. 6. Viverravus locality (UCM Loc. 81008) in the Lower Gray Member of the Wind River Formation. Isolated teeth and bones of vertebrates are a common constituent of the light colored horizon. Note that the uppermost strata on the ridge in the background represent a variegated sequence of strata assigned to the Lost Cabin Member.

sequence is more abrupt than occurs in the Red Creek section, suggesting a possible unconformity between the two units. A shoestring channel sandstone lies near the base of this sequence. Mottled red mudstones are brightly colored and less fossiliferous. A tabular carbonaceous shale is found near the base of this sequence which is locally important in correlation. A claystone unit lies at the base of the variegated sequence, which contains the associated skeletal remains of Coryphodon sp., isolated teeth of P. borealis and other vertebrates (UCM Loc. 80090).

A possible remnant of an upper gray sequence similar to the upper gray sequence of the Red Creek section is preserved in the SE ¼ of Sec. 22, T. 38 N., R. 87 W., to the south of the Deadman Butte traverse. Covered section and several faults prevent conclusive lithostratigraphic placement. It consists of 84 ft. (25 m) of drab colored mudstones and sandstones. Gray mudstones in this sequence are more fossiliferous than recorded in gray mudstones of any other area in the Red Creek-Deadman Butte area. One of these fossiliferous horizons (Palaeosyops jaw locality, UCM Loc. 81010) preserves associated skeletal elements of P. borealis, numerous other mammals, but few lower vertebrates. This unit is unique in preserving calcified wood in some abundance. Mudstones have sharp lithologic and color contacts with adjacent units and are composed primarily of clay with some sand and silt particles. Sandstones are friable, tabular and very fine to medium grained. No fossil vertebrates were recovered from these sandstones.

Rainbow Butte Stratigraphic Section (Plate II; Appendix A)--The Rainbow Butte section is 75 ft. (23 m) thick and was measured in the center of the N ½ of Sec. 19, T. 38 N., R. 87 W. on the west side of Red Creek, opposite exposures of the variegated sequence of the Lost Cabin Member in the Red Creek section. Neither the base nor the top of the Wind River Formation is exposed. The strata in this section consist of alternating mottled red-gray and gray mudstones, which are similar in lithology to the variegated sequence of the Red Creek section, and drab colored sandstones, which differ from the sandstones of the variegated sequence in the Red Creek section in having basal conglomerates which contain a higher percentage of Paleozoic and Mesozoic rock fragments. Preliminary reconnaissance work to the west suggests that quartzite (Flathead (?) Formation) and Paleozoic limestone and dolomite pebbles and cobbles become very common in this direction. Eleven of 25 stratigraphic horizons are fossiliferous.

Davis Ranch Stratigraphic Sections (Plate II; Appendix A)--The Davis Ranch stratigraphic sections were measured in Sec. 36, T. 38 N., R. 88 W. and Sec. 6, T. 37 N., R. 87 W. A composite thickness of 222 ft. (68 m) of strata were measured. Strata of the Wind River Formation in these stratigraphic sections are well known for their abundant fossil vertebrates (Davis Ranch locality, AMNH; 5 mi. North and East of Arminto, PU; Locality 1 of Guthrie, 1971). The lithology of the strata in these sections is quite similar to the lithology of the variegated sequence in the Red Creek and Deadman Butte sections and is a probable lithostratigraphic equivalent. This set of strata is characterized by brightly colored, variegated mudstones and abundant channel sandstones (Figs. 7, 8).

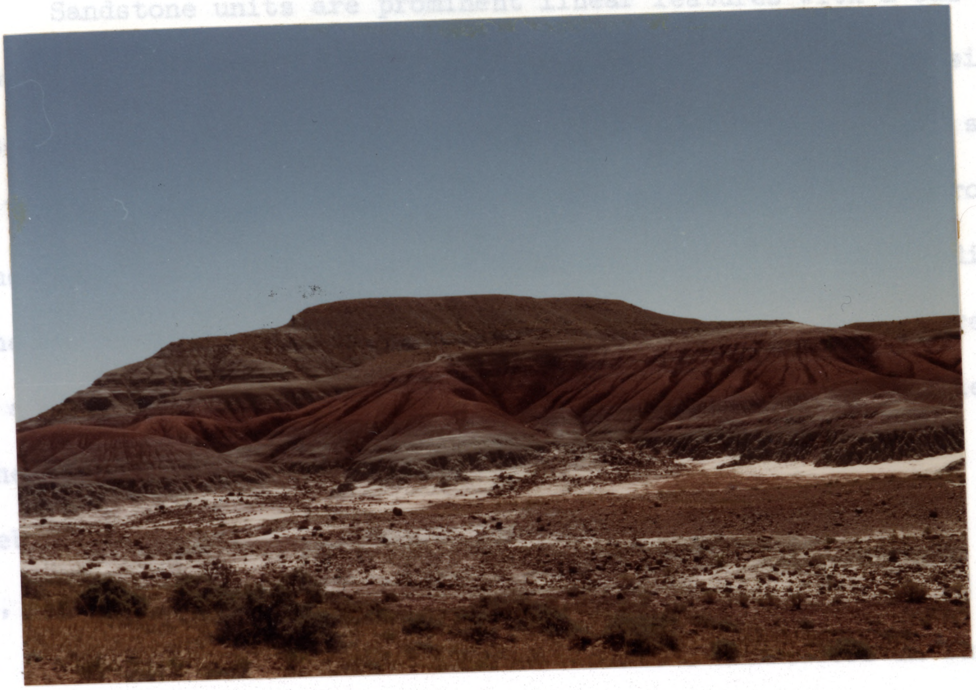

Fig. 7. Variegated sequence of the Lost Cabin Member at Davis Ranch, NW¼ Sec. 6, T. 37 N., R. 87 W. (Locality 1 of Guthrie, 1971). Dark colored band in middle of exposure is the "dark red stratum" of Granger (1910).

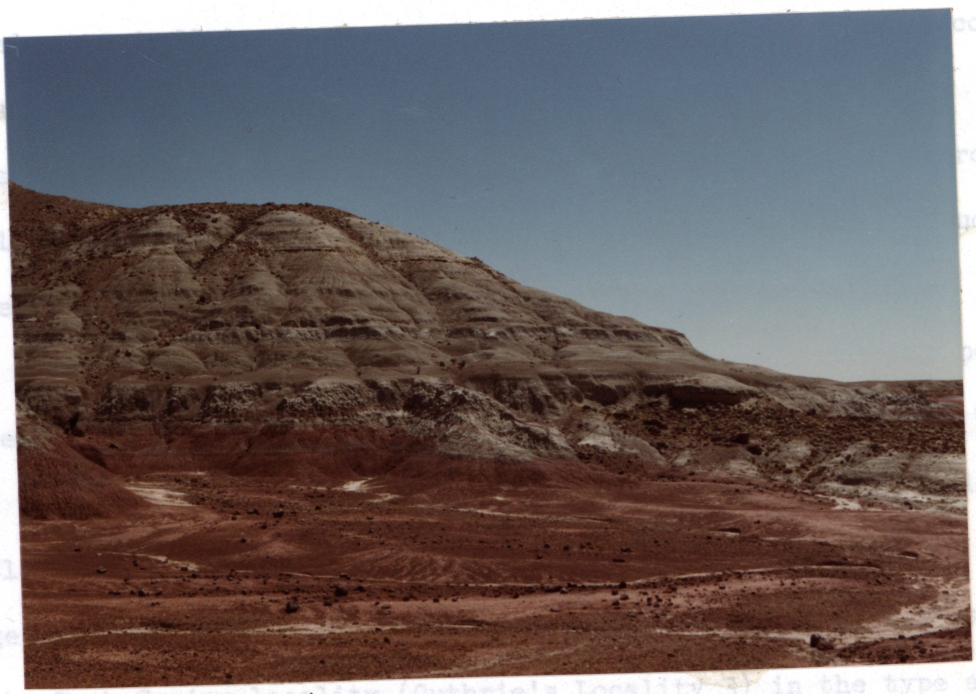

Fig. 8. Apron-channel sandstone in variegated sequence at Davis Ranch. Note that channel has cut into dark colored unit.

Sandstone units are prominent linear features with a calcareous cement. Sandstone geometry in the Davis Ranch area is similar to sandstones from the variegated sequence of the Red Creek section but on a much larger scale. They are best described as apron-channel sandstones. Fossil vertebrates are rare in the main bodies of the sandstones, but laterally these grade into red, mottled red-gray and gray mudstones where calcareous glaebules and pedotubules, eggshell fragments, coprolites and invertebrates are common and vertebrate fossils are extremely abundant (e.g., UCM Loc. 79043, q.v., Appendix B).

One sandstone unit was followed for two kilometers in surface outcrop and can easily be recognized on topographic maps. The sandstone measures 60 ft. (18 m) thick and extends laterally for 150 ft. (46 m) (estimated). This sandstone is multistoried, well sorted, crossbedded and channeled into lower mudstone units. Occasional carbonaceous shales lie lateral to the major part of the sandstone. This sandstone intertongues with mudstone units approximately halfway up from its base and cuts into the mottled red mudstone discussed next.

One mottled red mudstone (UCM Loc. 79042) is laterally persistent and important in correlating the Davis Ranch sections. This unit was traced for three kilometers in surface outcrop. Guthrie (1971, p. 50) referred to this unit as the "maroon shale" layer and suggested that it was the same unit as a maroon shale unit exposed at the Buck Spring locality (Guthrie's Locality 3) in the type area of the Lost Cabin Member (but see below, p. 42). Granger (1910, p. 242) implied the same correlation.

This mottled red unit (UCM Loc. 79042) is dark reddish brown (10 R 3/4) in color (see Fig. 8). The unit grades upward into a red-green-yellow-rust brown mottled mudstone. In the brightly red colored part of this mudstone it consists primarily of clay with some silt sized particles; very little sand is present. Calcareous glaebules and pedotubules are abundant throughout, and fossil vertebrates are more abundant in this mudstone than in any other fossiliferous horizon studied. Teeth and jaw fragments of mammals are the most common fossil found. Calcareous glaebule masses often cover the toothed areas of jaw fragments. Bones from this horizon show an orange-white color and teeth are black or translucent gray and brown. Skeletal elements of single mammal, turtle and crocodile individuals are sometimes associated, whereas fish remains are uncommon and are not certainly known to be associated.

Most fossil vertebrates from the American Museum Davis Ranch locality, Princeton Museum 5 mi. North and West of Arminto locality, University of Colorado Museum Loc. 79042 and Carnegie Museum Sullivan Ranch locality (all referred to as Locality 1 by Guthrie, 1971) come from this horizon. Fossil vertebrates are represented by abundant remains of Palaeosyops borealis and less abundant remains of Hyrachyus sp., cf. H. eximius. No Lambdotherium material is known from this fossiliferous horizon (see below and Chapter III).

Sediments below this mottled red mudstone differ in various exposures. Below this horizon sediments are variegated and similar in lithology and fossil content to the mottled red mudstone and, in general, similar to the variegated sequences in the Red Creek and

Deadman Butte sections. In the NE ¼ of Sec. 6, T. 37 N., R. 87 W., underlying sediments are primarily gray and poorly fossiliferous. However, in all areas of exposure a gray mudstone and sandstone lie below the mottled red horizon. Only the mottled red horizon and the channel sandstone can be traced between these two exposures.

Sediments above the mottled red mudstone are preserved in the NW ½ of Sec. 6, T. 37 N., R. 87 W. All of these upper strata are gray and intertongue with the large channel sandstone unit discussed above. A probable volcanic ash is preserved approximately 30 ft. (9 m) above the mottled red mudstone and was traced to the butte at 6,005 ft. (1,830 m) in elevation in the NE ¼ of Sec. 12, T. 37 N., R. 88 W. Fossil vertebrates and calcareous glaebules and pedotubules occur in gray mudstone units both above and below this ash bed. Fossils from these upper gray strata are better preserved than those from the mottled red mudstones. Associated remains of mammals are more common, whereas crocodiles and turtles are less common.

The sequence of strata preserved in the Davis Ranch area is similar to the variegated sequences of the Red Creek and Deadman Butte stratigraphic sections. These strata are assignable to the Lost Cabin Member of the Wind River Formation (Sinclair and Granger, 1911; Guthrie, 1971).

<u>Exposures North and East of Arminto</u>--Strata exposed in Secs. 1 and 12, T. 37 N., R. 87 W. were examined, but no stratigraphic section was measured. Keefer (1965a, 1970) has mapped both the Wind River Formation and Indian Meadows Formation in this area.

The Indian Meadows Formation was mapped by Keefer (1965a, p. 39) as a 50 ft. (15 m) thick "series of conglomerate beds containing sandstone, siliceous shale, and chert cobbles that unconformably overlie the Upper Cretaceous Cody Shale and underlie varicolored shales of the Wind River Formation." Strata in this area lie on the western limb of the Casper Arch and dip to the west at approximately 6 degrees. These conglomerates could represent the Lower Gray Member of the Wind River Formation.

The "varicolored shales" in these exposures superficially resemble the variegated sequence of the Red Creek, Deadman Butte and Davis Ranch sections. Although mottled red mudstones are similar in surface exposure, they differ from other mottled red mudstones discussed above in containing dark brown oxide glaebules and pedotubules and in not preserving abundant fossil vertebrates. Sandstones are tabular, well sorted quartz arenites. One sandstone (UCM Loc. 80063) contains numerous fossil vertebrates, many of which are water-worn and show post-depositional cracking and distortion. More field studies are needed to clarify the lithostratigraphic relationships of this area. The "varicolored shales" most likely represent the Lost Cabin Member of the Wind River Formation, at least in the upper part of the exposures.

<u>Buck Spring, Type Area of Lost Cabin Member</u> (Plate II; Appendix A)--The Buck Spring area in Secs. 15 and 22, T. 38 N., R. 89 W. probably represents part of the type area of the Lost Cabin Member of the Wind River Formation as originally understood by Sinclair and Granger (1911). Sinclair and Granger (1911, p. 105) indicated that the "type area of the Lost Cabin formation is to the

east of Lost Cabin along Alkali Creek and on the divide between Alkali and Poison Creeks." Keefer (1965a) and Korth (1982) give the location of the type area as the northeastern part of T. 38 N., R. 89 W. Tourtelot (1948) has, however, presented a convincing argument that the type area "east of Lost Cabin" is in fact the exposures at Buck Spring (my inference from his discussion). Stratigraphic sections in this area measured by Tourtelot (in Keefer, 1965a) and myself are nearly identical to a stratigraphic section measured by Granger (1910, p. 242) "eight miles east of Lost Cabin." This is the same area figured by Osborn (1929, Plate VI-B) as typical Lost Cabin exposures. The type area "on the divide between Alkali and Poison Creeks" probably lies along Frenchie Draw in Secs. 9, 10, 11, 14, 15 and 16, T. 37 N., R. 90 W. (east of the highway between Moneta and Lysite).

Neither the base nor the top of the Wind River Formation or Lost Cabin Member is exposed in the Buck Spring area. A total of 109.5 ft. (33.4 m) of Lost Cabin Member sediments were measured in surface outcrop. However, Keefer (1965a) has suggested that the maximum thickness of the Lost Cabin Member could be as much as 2,000 ft. (600 m). Two lithologic sequences can be generally distinguished, a lower gray and a variegated sequence. Both of these sequences were included in the original description of the Lost Cabin Member (Sinclair and Granger, 1911).

The lower gray sequence in the Buck Spring area, which is best exposed along Alkali Creek near the town of Lysite and on the divide between Alkali and Poison Creeks, consists primarily of gray mudstones and yellow and gray sandstones. The sandstones generally have either an apron-channel or tabular geometry. Conglomeratic beds are very rare, and where they occur they contain primarily Precambrian clasts, intraformational mudstone clasts and occasional water-worn fossil teeth and bone fragments. Gray mudstones are siltstones and occasionally purple-mottled. Some calcareous glaebules and pedotubules are present. These gray mudstones are poorly fossiliferous.

The variegated sequence in the Buck Spring area of the Lost Cabin Member is characterized by alternating mottled red and gray mudstones and apron-channel sandstones. Some variegated mudstone units have prominently banded alternating red and greenish gray mudstone horizons with each band having an undulatory appearance and varying between approximately one inch (0.02 m) and one foot (0.30 m) in thickness. These banded mudstones are laminated and contain a small percentage of sand and silt. These units were observed only in the Buck Spring area and occur directly above the mottled purple mudstone ("dark red stratum"). Locally they contain abundant calcareous glaebules and extremely well preserved and associated remains of fossil vertebrates. The partial skeleton of <u>Palaeictops multicuspis</u> (UCM 46284) and associated dentary and fragmentary skull of <u>Notharctus</u> sp., cf. <u>N</u>. <u>venticolus</u> (UCM 47674) were recovered from these banded mudstones (Fig. 9).

Of particular importance is a mottled purple mudstone exposed near the base of most exposures in the Buck Spring area (UCM Loc. 81029). Granger (1910), Keefer (1965a) and Guthrie (1971) have commented on this horizon because of its lateral persistence and abundant fossil vertebrates.

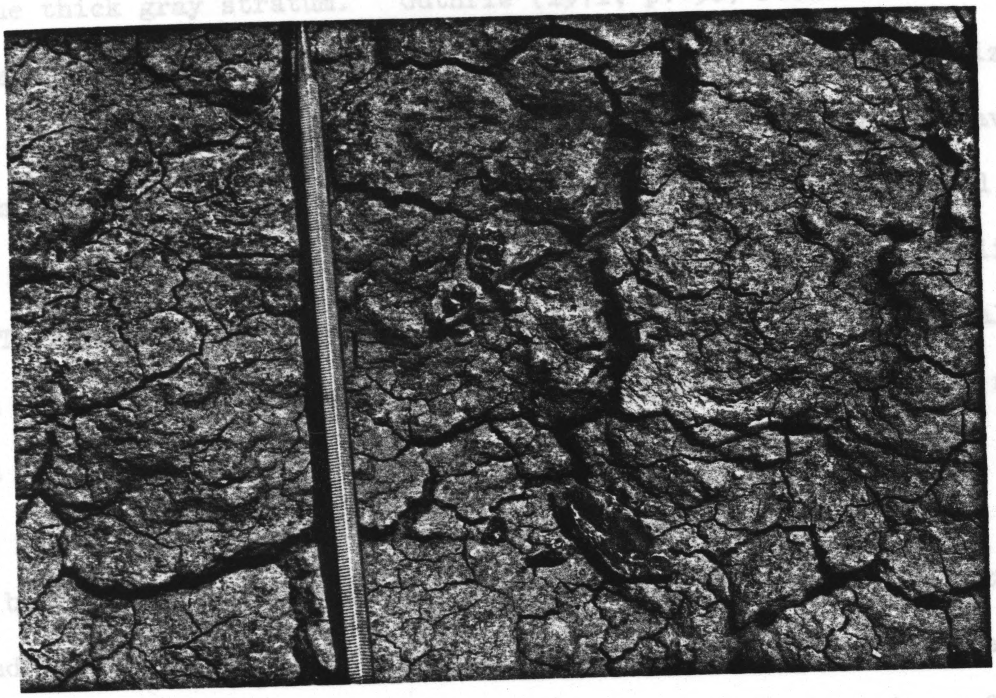

Fig. 9. Lower jaw and fragmentary skull of <u>Notharctus</u> sp., cf. <u>N. venticolus</u> (UCM 47674) in situ at the Buck Spring locality (UCM Loc. 81032).

Granger (1910, p. 242) referred to this horizon as the "dark red stratum" which "could be identified for twenty miles along Alkali Creek, partly by its peculiar coloring and partly by the presence, always, of numerous fragmentary fossils; wherever seen it was resting on the thick gray stratum." Guthrie (1971, p. 50) referred to this horizon as the "maroon shale" which he believed was the same horizon as a dark red unit exposed at his Locality 1 (discussed above, Davis Ranch stratigraphic sections), and Locality 2. He also suggested that this "maroon shale" correlated with gray strata at his Locality 4. These relations suggested to Guthrie that "nearly all material from these localities was collected in a vertical interval of no more than 40 feet" (ibid.).

At Buck Spring, the "dark red stratum" or "maroon shale" unit can be followed and traced in all exposures. This horizon is between 8 and 15 ft. (2.4-4.6 m) thick and is a poorly sorted mottled grayish red (10 R 4/2) mudstone with anastomizing very pale green (10 G 8/3) striae. These striae may be remnants of rhizoliths (see Klappa, 1980). The unit contains a relatively high percentage of fine to medium quartz grains and is micaceous. Calcareous glaebules are locally important, but pedotubules are rare. These lithologic characters occur throughout its thickness and lateral extent. The unit is cut into by a light green colored apron-channel sandstone in Sec. 15, T. 38 N., R. 89 W. Further to the south in Sec. 22, the unit is overlain by banded mudstones. Fossil vertebrates are extremely common, dominated in order of abundance by turtle shell fragments, crocodile scutes and isolated teeth of mammals. Mammal jaws are extremely rare in this unit, with a ratio of isolated teeth of mammals to jaw fragments greater than 50:1. No associated skeletal elements of a single mammal individual were observed. Isolated teeth and bone fragments from this horizon are always black in color and often have a thin veneer of an iron oxide mineral. Rare jaw fragments of mammals (less than ten specimens known) are distorted by post-depositional crushing. Identified mammal remains are typical of mammals recovered from the Lambdotherium zone in the Red Creek and Deadman Butte stratigraphic sections. Lambdotherium is abundant. No remains of Palaeosyops borealis or Hyrachyus sp., cf. H. eximius are known from this horizon. Osborn (1929) did, however, report that the type specimen of P. gregoryi was found 100 ft. (30 m) above this unit. Osborn also reports the type specimens of P. borealis and L. popoagicum come from this horizon. Because these were collected in 1880, when no precise locality data was kept, this must be viewed with some circumspection.

Supposed Correlation of Granger's "Dark Red Stratum" and Guthrie's "Maroon Shale" Layer in the Lost Cabin Member

As described above, the "dark red stratum" or "maroon shale" measured in the Davis Ranch stratigraphic sections differs in a number of criteria from the "dark red stratum" or "maroon shale" in the Buck Spring area, the designated type area of the Lost Cabin Member (this report and Sinclair and Granger, 1911; sensu Granger, 1910; Tourtelot, 1948). Criteria apparently used by both Granger (1910) and Guthrie (1971) to correlate these two distinctive horizons include: 1) dark red color; 2) high fossil content; and 3) superposition above a dark gray stratum. The following observations suggest that the hypothesis that the "dark red stratum" or "maroon shale" at Guthrie's Locality 1 and Locality 3 represent the same fossiliferous unit is false:

1) The sediments of the two units in these different areas are different in color pattern, particle content, and the relative distribution of calcareous glaebules and pedotubules;

2) Fossil vertebrates from the two horizons were diagenetically altered in different ways (crushing, coloration and probable mineralogical content of encrustation);

3) The two units preserve a fossil vertebrate assemblage that was subjected to differing taphonomic histories (bone element preservation, associated skeletal parts of individuals, and proportions of lower vertebrate and mammal taxa; Appendix B);

4) Almost all red units in the Wind River Formation are underlain by dark gray strata; and

5) The two fossiliferous horizons are in different biostratigraphic zones of the Wind River Formation (Chapter III).

These observations suggest that these two horizons differ lithostratigraphically, biostratigraphically and chronostratigraphically and do not represent the same horizon in any sense (Hedberg, 1976, p. 14). The Davis Ranch strata lie some 8 mi. (13 km) from the Buck Spring type area of the Lost Cabin Member, where the intervening area is grass covered. Any lithostratigraphic correlation of the two fossiliferous mudstone units must be done by subsurface sampling. The erroneous assumption that these two units were the same has resulted in a misunderstanding of the mammalian biostratigraphy of the upper part of the Wind River Formation.

Summary of Lithostratigraphic Correlation of the Wind River Formation, Red Creek-Deadman Butte and Buck Spring Areas

A Lower Gray Member measured at the base of the Red Creek and Deadman Butte stratigraphic sections as a lower gray sequence is a mappable unit of the Wind River Formation (see Stucky and Krishtalka, 1982). It was deposited on an erosional surface of considerable relief on Mesozoic strata (Tourtelot, 1953; Woodward, 1957). As far as known, this member occurs only at the base of the Wind River Formation in the central part of T. 38 N., R. 87 W. from Secs. 18 to 25. The member becomes somewhat thicker to the east and is characterized in all sections by gray tabular sandstones and mudstones, occasional tabular dark gray claystones and rare tabular and lenticular carbonaceous shales. The sandstones are quartz arenites and consist primarily of well rounded to rounded, fine to medium, quartz sand grains (presumably eroded from the Morrison and Cloverly Formations). Conglomerates commonly occur in sandstones as well separated lenses. These conglomerates are composed of pebble to cobble sized clasts derived principally from Mesozoic strata (subangular and angular porcelainite from the Mowry shale; subrounded chert pebbles and rounded sandstone and conglomerate rock fragments from the Morrison and Cloverly Formations; chert and fossil fragments from the Sundance Formation; and sandstone and chert fragments from the Chugwater Formation), but also contain some Paleozoic rock fragments (subrounded limestone fragments). The sandstones are more fossiliferous than the mudstones. The mudstones are primarily siltstones, many of which contain abundant gypsum crystals. Some mudstones contain bioturbation structures and calcareous glaebules. Dark gray claystones are laminated and are useful marker beds.

This Lower Gray Member differs from the Lysite and Lost Cabin Members in the following characteristics (compare criteria established for the Lost Cabin and Lysite Members by Tourtelot, 1948): 1) Clasts in sandstones and conglomerates are derived principally from Mesozoic rocks; 2) Sandstones are tabular in geometry, laterally extensive, and contain well separated sets of conglomeratic lenses; 3) Fossil vertebrates (isolated teeth and bone fragments) are a common constituent of sandstones; and 4) Mudstones are almost exclusively gray in color; mottled red or red mudstones are almost entirely absent.

This Lower Gray Member probably intertongues with variegated strata of the Lost Cabin Member to the east and south, as suggested by biostratigraphic data. The Lower Gray Member is within the Lambdotherium range zone throughout its exposures (Lostcabinian).

The Lost Cabin Member of the Wind River Formation lies conformably on the Lower Gray Member in the Red Creek and Deadman Butte stratigraphic sections. The Lost Cabin Member in these areas is composed of a lower variegated sequence and upper gray sequence. In the Buck Spring area the member consists of a variegated sequence overlying a gray sequence of strata (see Sinclair and Granger, 1911), whereas north and east of Arminto only a variegated sequence is exposed. At Davis Ranch, the Lost Cabin Member is represented by a set of prominently colored variegated beds which intertongue with a gray sequence in the lower part of the section and are overlain by a gray sequence of strata.

Strata of the Lost Cabin Member are characterized by apron-channel and shoestring channel sandstones and both variegated and gray mudstone sequences of strata. Sandstone bodies often cut into and intertongue with mudstones, and are prominent linear features. Sandstones are principally composed of fine to coarse, subangular to rounded quartz and rock fragments. Conglomerates are uncommon in the member in the Red Creek-Deadman Butte and Buck Spring areas, but where they occur they are composed primarily of rounded Precambrian rock fragments and intraclasts. Upsection and basinward sandstone bodies trend toward larger size (see Seeland, 1978). These large scale channel sandstones are prominent linear features which are crossbedded and are associated with carbonaceous shales.

Mudstone sequences vary from variegated to gray sets of strata throughout the Lost Cabin Member. Mottled red mudstones are commonly more fossiliferous than are gray mudstones and often contain abundant calcareous glaebules and pedotubules. Mottled red mudstones are often laterally persistent and can be used as marker beds within local exposures.

Gray mudstone sequences of the Lost Cabin Member are preserved both above and below variegated sequences. Gray mudstone sequences are more poorly fossiliferous than are variegated sequences of the Lost Cabin Member. Poorly fossiliferous gray mudstone units often have sharp lithologic lower contacts, show graded bedding, and seldom show bioturbation structures in hand samples. Gray mudstones that are fossiliferous generally have calcareous glaebules and pedotubules.

In the Lost Cabin Member both variegated and gray sequences are of only local significance and cannot be used for lithostratigraphic correlation on a regional scale. Interregional correlations of colored sets of strata must be supported either by subsurface data or by detailed field studies of both lithostratigraphy and biostratigraphy.

The Lost Cabin Member exposures in the lower part of the section at Buck Spring are used to define the *Lambdotherium* range zone (Lostcabinian subage) along with the Lower Gray Member sediments in the northern part of the Red Creek-Deadman Butte area. Lost Cabin Member deposits in the upper part of the section at Buck Spring and in the Red Creek, Deadman Butte, Rainbow Butte and Davis Ranch stratigraphic sections are used to define the *Palaeosyops borealis* assemblage zone (Gardnerbuttean subage) (Chapter III).

Depositional Environment

Keefer (1965a), Soister (1968), Seeland (1978), Korth (1982) and others have discussed the depositional environments of the Wind River Formation. Love (1978) has recently reviewed the tectonic background necessary for understanding the depositional environments of the Wind River Formation in the Badwater area. The present topography of the mountain fronts nearly represents the fossil topography and erosion surface during the deposition of the Wind River Formation in the Red Creek-Deadman Butte area (Woodward, 1957). Interpretations of the climatic conditions during the time of Wind River Formation deposition have been reviewed by Soister (1968) and Seeland (1978). Botanical evidence indicates the climate was "warm-temperate" (Barry, 1930, p. 60), "humid, subtropical" (Leopold and MacGinitie, 1972, p. 161), or "between paratropical and subtropical" (MacGinitie, 1974, p. 40). Most researchers agree that the climate was not tropical.

Two facies can be distinguished in the Wind River Formation, a mountainward and a basinward (Keefer, 1965a). The mountainward facies is represented by the Lysite and Lost Cabin Members close to their source areas (Tourtelot, 1948; Korth, 1982) and by the Lower Gray Member in the Red Creek-Deadman Butte area. The Lower Gray Member, however, differs somewhat in its depositional environment as a result of differences in paleotopography and the amount of tectonic activity in its source area. The basinward facies is represented by typical deposits of the Lost Cabin Member in the Red Creek-Deadman Butte area, at Buck Spring and throughout most of the interior of the basin (Keefer, 1965a).

The Lysite and Lost Cabin Members in the Badwater area, close to their sources and near areas of major tectonic activity (Love, 1978), are dominated by interbedded sandstones and conglomerates which become less common basinward (Tourtelot, 1948; Keefer, 1965a; Korth, 1982). Korth (1982) has interpreted these near source sediments as alluvial fan deposits. Seeland (1978) indicates that alluvial fans in the Wind River Formation are steep, do not show a radial pattern, and thus did not extend far into the basin interior.

Angular relations of the Lower Gray Member on Mesozoic strata in the Red Creek-Deadman Butte area suggest that dip slopes of the paleolandscape were moderate there (approximately 10 degrees, but in some areas up to 45 degrees, see Plate I; Tourtelot, 1953; Keefer, 1965a). Practically all sand and larger sized clasts in the Lower Gray Member are derived directly from these Mesozoic strata. This member is dominated by laterally extensive tabular sandstones with interbedded conglomeratic lenses and lacks any evidence of debris flows. These suggest that the Lower Gray Member represents a braidplain off of the gently dipping highland areas where Mesozoic strata was exposed (see Rust, 1979). Streams coming off of the highland areas that deposited the sandstones and interbedded conglomerates were variable in competence as indicated by varying clast and fossil sizes (Stucky and Krishtalka, 1982). These streams probably had catchment areas near the size of small semipermanent streams presently draining the area (e.g., Red Creek), principally because of the landscape similarities between then and now.

Tabular mudstones and claystones suggest occasional deposition of sediment load deposits during overbank flooding. Some mudstones preserve bioturbation structures (burrows and rhizoliths) and pedogenic structures (calcareous glaebules) that indicate they were subareally exposed for substantial periods of time. These mudstones represent probable paleosols (Bown, 1979; Bown and Kraus, 1981a, 1981b).

Sandstone and mudstone units in the Lost Cabin Member of the Red Creek-Deadman Butte and Buck Spring areas represent a shift in depositional environment to the basinward facies. Sediments in these areas were deposited basinward from the mountainward alluvial fan deposits of the Lost Cabin and Lysite Members and braidplain deposits of the Lower Gray Member.

Sandstones of the Lost Cabin Member in more basinward areas have primarily apron-channel and shoestring channel geometries, contain fewer conglomeratic lenses, and are composed of clasts from more distant Precambrian sources. These sandstones are often prominent linear features that intertongue with and cut and grade laterally into mudstones. These criteria suggest that the Lost Cabin Member in these areas was deposited by streams on broad flood plains with greater catchment areas than streams in the Lower Gray Member (see Walker and Cant, 1979). These streams were relatively straight, as shown by a lack of high sinuosity (Seeland, 1978).

A trend in larger size of apron-channel sandstones toward the central part of the basin suggests that streams were much larger toward the basin axis. Intertonguing of sandstones with mudstones and relatively large vertical and horizontal intervals between channel sandstone bodies with intervening mudstones suggest that channel movement occurred by avulsion.

Mudstones of the Lost Cabin Member reflect the overbank deposits of these streams on a relatively broad floodplain. Mudstones that have sharp subjacent lithologic contacts, show graded bedding and basal intraclasts, and are laterally persistent indicate that flood plains were indeed quite broad. Short intervals of time between depositional events are indicated for these mudstones by the presence of these primary structures and a general lack of bioturbation or pedogenic characteristics.

However, many mudstones in the basin proper do suggest extended periods of time between depositional events. Bioturbation structures (calcareous pedotubules, burrows, rhizoliths), pedogenic characteristics (calcareous glaebules and color mottling in some of these), and lack of primary depositional structures in hand samples suggest this. Often, these mudstones preserve abundant and diverse fossil vertebrates, coprolites, eggshell fragments, invertebrate fossils and silicified and occasionally calcified wood and plant fragments. Some fossil bones show subareal pre-burial weathering and carnivore or rodent gnawing. Both large and small bodied vertebrates are preserved together as are aquatic and terrestrial vertebrates. Some terrestrial species are represented by associated remains of single individuals, whereas completely aquatic vertebrates (fish) are represented almost exclusively by isolated scales, jaw fragments and vertebrae. These data all suggest that these mudstones are remnants of paleosols (Bown, 1979; Bown and Kraus, 1981a, 1981b).

These data fit well with Seeland's (1978) model for the Paleo-Wind River drainage system, where the Red Creek-Deadman Butte sediments reflect tertiary and secondary stream tributaries draining into the Paleo-Wind River. The landscape of the Wind River Basin during the deposition of the Wind River Formation was very similar to what it is today--highland and mountainous regions surrounding a broad, relatively flat, plain with numerous meandering tributaries of the Paleo-Wind River flowing toward what is now the basin axis or the actual stream valley of the Paleo-Wind River (Seeland, 1978). The major differences between then and now are that during the deposition of the Wind River Formation the periphery of the basin was shaken by tectonic activity and the central portions of the basin were being rapidly filled by sediment eroding off of the highlands. The vast central plain was also covered by a paratropical to subtropical forest (MacGinitie, 1974).

Middle (?) Eocene Volcaniclastic Sequence

A dark brown colored volcaniclastic sequence lies conformably on top of the upper gray sequence of the Wind River Formation, which was measured in the Red Creek stratigraphic section. No detailed lithologic or petrographic studies have been done for this unit. It is well exposed in the SW ¼ of Sec. 30, and NE ¼ of Sec. 31, T. 38 N., R. 87 W. Thickness of this unit is 91 ft. (28 m). The top of the sequence is unconformably overlain by Quaternary gravels.

Three horizons which were found throughout the exposures of the sequence were measured. The lowermost horizon is 7 ft. (2 m) thick. This unit is a pale olive green mudstone with high clay content and some coarse subangular quartz grains. The surface of this unit is littered with euhedral gypsum and calcite crystals and spheroidal barite crystal clusters. Aquatic fossil vertebrates are common, dominated by fish, turtles and crocodiles. No mammals are known.

The middle horizon is a carbonaceous shale 4.5 ft. (1.5 m) thick. The unit is yellowish-brown in color and is thinly laminated. Well preserved leaf and seed fossils were found in some outcrops of this horizon. The lower contact of this carbonaceous shale is sharp with the lower mudstone unit.

The upper unit is a massive volcaniclastic paraconglomerate which is 80 ft. (25 m) thick, and poorly sorted. Clasts in this unit vary in size from very fine sand to cobble size. Pebble to cobble sized clasts consist of brown claystone balls and well rounded volcanic (red, green and brown basalt) rock fragments. Pebbles and cobbles are sand matrix supported. Some lenticular carbonaceous shales and mudstone units with bedding planes parallel to strike are enclosed within the volcaniclastic paraconglomerate. Seeland's (1978) paleocurrent data would suggest these deposits were derived from the northwest. This unit is conformable on the lower carbonaceous shale unit. Fossil vertebrates are, however, very rare.

Several mammal tooth fragments were found in the volcaniclastic paraconglomerate including Hyopsodus paulus and a tooth fragment of an equid which most closely resembles Hyracotherium vassacience (UCM Loc. 80064-C). These taxa suggest an early or middle Eocene age (Chapter III). The base of this unit lies 325 ft. (99 m) above the Someday locality (UCM Loc. 79040) of the variegated sequence of the Wind River Formation which preserves a probable early Bridgerian age fauna (see Chapter IV). This suggests that the volcaniclastic sequence is middle Eocene in age.

The volcaniclastic nature of this sequence suggests that it is a probable lithostratigraphic equivalent of either the Wagon Bed Formation exposed along Beaver Rim and north of the Cedar Ridge Fault in the Badwater area (Van Houten, 1964; Love et al., 1978) or the Aycross Formation of the Absaroka Range (Love, 1939; Bown, 1982). Love (written communication, 1982) will map this unit as part of the Wagon Bed Formation on the USGS Wyoming geological map.

CHAPTER III

BIOSTRATIGRAPHIC ZONATION--UPPER PART OF THE WIND RIVER FORMATION

Introduction

The purpose of this chapter is to document the biostratigraphic distribution of mammalian taxa in the upper part of the Wind River Formation. Two biostratigraphic zones are defined on the basis of the occurrence of key mammalian taxa in the Red Creek, Deadman Butte and Buck Spring (type area of the Lost Cabin Member) stratigraphic sections: a _Lambdotherium_ range zone (_Lambdotherium_ zone) and a _Palaeosyops borealis_ assemblage zone (_Palaeosyops borealis_ zone). These occurrences are augmented by faunal lists from well sampled Lost Cabin Member fossil vertebrate localities (Localities 1, 2, 3 and 4 of Guthrie, 1971).

The recognition of the Lambdotherium and _Palaeosyops borealis_ zones allows for a more precise biostratigraphic correlation of the Wind River Formation with other formations in western North America which are of late early or early middle Eocene age. Indeed they suggest criteria for determining an objective definition of the Wasatchian-Bridgerian boundary in continental deposits of the western interior region of North America (Chapter IV).

Biostratigraphic Purpose

Biostratigraphic studies have proved invaluable for determining the relative age and time intervals during which a body of sedimentary strata was deposited. Relative proportions and occurrences of key taxa have allowed for broad based correlations between different mappable lithostratigraphic units. At present the relative age of most formally recognized lithostratigraphic units in North America is well known. With the development and use of improved chronostratigraphic methods, such as magnetostratigraphy and radiometric dating, relative ages determined by biostratigraphic data have been corroborated and refined. With continued biostratigraphic and chronostratigraphic studies, a more accurate and precise time correlation of geologic, physical and biologic phenomena will be accomplished.

Recently the biostratigraphic record has been used to test, understand and develop evolutionary theory (see Kauffman and Hazel, 1977). Gingerich (1979b and references therein) has especially emphasized the utility of a well documented biostratigraphic record for understanding evolutionary patterns in Eocene fossil vertebrates. While his systematic methods and results have not been without controversy, his basic biostratigraphic methodology for the study of fossil vertebrate evolution has influenced subsequent studies (e.g., Bown, 1979a; West, 1980; Rose, 1981). The essential feature of this biostratigraphic methodology that is advocated here is the sequential ordering of fossil materials (see also Kauffman, 1977; Savage, 1977). Once this has been accomplished, the fossil materials can be analyzed diachronically, with an evolutionary theoretic framework in mind. Studies of fossil material which do not incorporate time-order relate phenomena in a structural-functional way and are synchronic (cf., Radcliffe-Brown, 1955). It is only when time relations are incorporated that these studies become diachronic and evolutionary.

Although the results of this research have been the documentation of biostratigraphic relations, the overall goal is to use this data for understanding evolutionary process and patterns at both the species and assemblage levels. This goal is beyond the scope of this contribution but has determined the methodologies used. Future studies will be directed toward this goal.

Biostratigraphic Methodology

The primary data from which evolutionary patterns and processes can be understood begins with the concepts of fossiliferous horizon, assemblage and species. These require operational definitions (Reynolds, 1971) which are derived from the general theories of stratigraphy (e.g., American Commission on Stratigraphic Nomenclature, 1970; Hedberg, 1976), community ecology (e.g., MacArthur, 1972; Whittaker, 1975), and biological systematics (e.g., Simpson, 1961; Hennig, 1966). A general systems theory approach posits a relation of these concepts to the present living world, but they are defined upon the limits of their observation in the geological record.

A fossiliferous horizon is defined as a local stratigraphic unit which contains fossils that is minimally bounded by other units. Thus a fossiliferous horizon is: 1) a lithostratigraphic unit that is bounded by sharp or gradational boundaries with adjacent, lithologically different units (including fossil particle content and observable physical features, Article 4, Code of Stratigraphic Nomenclature, 1970); 2) a biostratigraphic unit that contains fossils contemporaneous with the deposition and upper erosional surface of the lithostratigraphic unit (Article 19, Code of Stratigraphic Nomenclature, 1970); and 3) a chronostratigraphic unit that represents an interval of time (Article 26, Code of Stratigraphic Nomenclature, 1970). Fossiliferous implies that this unit contains a set of fossils (Bates and Jackson, 1980), and horizon implies that this unit is a distinctive bed with a specific three dimensional location (see Hedberg, 1976).

The fossiliferous horizon is the minimal unit within biostratigraphy, faunal study and evolutionary analysis. The definition of the fossiliferous horizon presumes that the fossil specimens recovered from it are at least penecontemporaneous with one another and are at the lowest level of resolution in the fossil record for determining variation and cluster pattern for assemblages and species. Taphonomic study of a fossiliferous horizon can predict the relative proportion of bias due to time, space and accumulation environment on variation and cluster pattern in assemblages and species within and between fossiliferous horizons (see Behrensmeyer and Hill, 1980; Shipman, 1981; Bown and Kraus, 1981b).

No fossiliferous horizon is determined on the basis of an arbitrary interval of strata, and thus within a vertical thickness of strata the probability of the number of fossiliferous horizons is proportional to the frequency of occurrence in the entire sample.

Arbitrary intervals of strata as units of measurement in evolutionary studies are artificial because they are defined by convenience. Fossiliferous horizons, on the other hand, are defined by the characteristics of the geologic record and can repeatedly be recognized by more than one researcher.

An assemblage is "a group of fossils that occur at the same stratigraphic level; often with a connotation also of localized geographic extent" (Bates and Jackson, p. 38, 1980). An assemblage, then, is the set of specimens (usually reduced to a set of lithosympatric species, defined on p. 59) recovered from a single fossiliferous horizon.

The species concept in paleontology has been thoroughly discussed and defined (Sylvester-Bradley, 1956; Simpson, 1961; Van Valen, 1976; Wiley, 1978, 1979, 1981; Gingerich, 1979b; Lovstrup, 1979; Gould, 1981; Madden, 1981). Arkel (p. 99, 1956) points out that the species concept must be useful, and that "if too much weight is given to . . . the theoretical aspects of taxonomy . . . there is a tendency to rely and build on mere words and definitions instead of on the first-hand study of actual material."

Species are defined as sets of specimens which show continuous morphologic variation and unique character similarities. They are the morphologic species of Simpson (1961). This definition is selected primarily because it allows for hypotheses of morphologic variation and similarity that can be tested in the fossil record (cf., Gaffney, 1977).

The basic set of specimens from which species determinations are made is that recovered from a single fossiliferous horizon.

This reduces the amount of morphologic variation that is controlled by time or geographic variation. Specimens from two or more fossiliferous horizons may be grouped into the same species by their shared derived characters and nearly identical similarity. What is then of interest is the variation within and between clusters of specimens (species) both within and between fossiliferous horizons.

From the concepts of fossiliferous horizon and species follow the concepts of lithosympatry, lithoparapatry and litho-allopatry. Lithosympatric species are clusters of specimens divisible on morphological criteria that occur within the same fossiliferous horizon. Lithoparapatric species are clusters of specimens divisible on morphologic criteria that overlap in biostratigraphic occurrence but are not known to occur together within the same fossiliferous horizon. Lithoallopatric species are clusters of specimens divisible on morphologic criteria that do not overlap in biostratigraphic occurrence. Any two or more species may be lithosympatric, lithoallopatric and lithoparapatric in different parts of their stratigraphic occurrence (Fig. 10).

Using the fossiliferous horizon as the basic unit in biostratigraphy will allow for a more precise biostratigraphic zonation of sedimentary rocks. Arbitrary sampling intervals or collections of fossils from areas which represent more than a single fossiliferous horizon are less precise and less useful for either biostratigraphic or evolutionary studies. Systematic studies should begin with the assemblage of specimens from a single well represented fossiliferous horizon to avoid major biases of geographic and time variation. As Lamarck (1912; original 1809) and Darwin (1859)

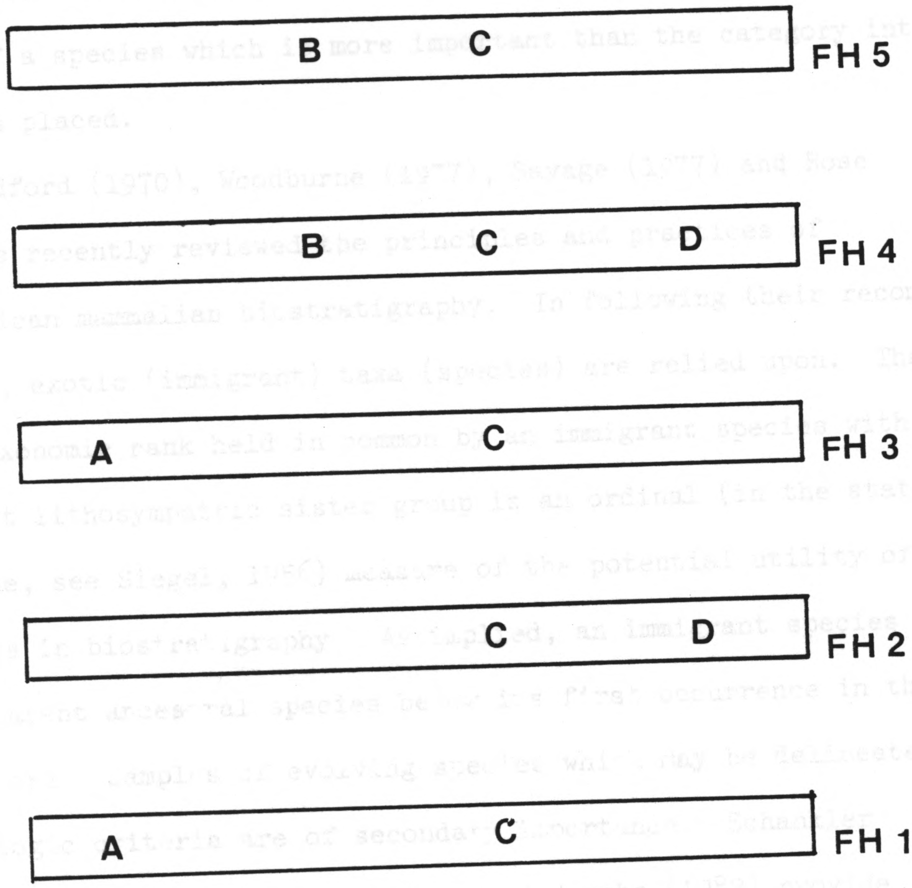

Fig. 10. Stratigraphic distribution of four mammalian species (A,B,C,D) in five fossiliferous horizons (FH) to illustrate the concepts of lithosympatry, lithoparapatry, and lithoallopatry. Species A and B are lithoallopatric in this stratigraphic record. Species A and D are lithoparapatric in FH2 and FH3, but lithoallopatric in FH1 and FH4. Species A and D also never occur in lithosympatry. Species B, C, and D occur in lithosympatry only in FH4, but species B and C occur in lithosympatry in FH4 and FH5 whereas species C and D occur in lithosympatry in FH2 and FH4. Many other permutations are present. The terms lithosympatry, lithoparapatry and lithoallopatry apply to local stratigraphic sections. See text for definitions of fossiliferous horizon and species.

emphasized over a century ago, it is the sorting out of the variation patterns of a species which is more important than the category into which it is placed.

Tedford (1970), Woodburne (1977), Savage (1977) and Rose (1981) have recently reviewed the principles and practices of North American mammalian biostratigraphy. In following their recommendations, exotic (immigrant) taxa (species) are relied upon. The highest taxonomic rank held in common by an immigrant species with its closest lithosympatric sister group is an ordinal (in the statistical sense, see Siegel, 1956) measure of the potential utility of the species in biostratigraphy. As implied, an immigrant species has no apparent ancestral species below its first occurrence in the fossil record. Samples of evolving species which may be delineated by morphologic criteria are of secondary importance. Schankler (1980), Rose (1981) and Barry, Lindsey and Jacobs (1982) provide excellent examples of biostratigraphic zonation techniques. As many stratigraphic sections as possible should be used to insure a consistent zonation. Poorly documented fossil collections should be used with extreme caution. Isolated fossiliferous horizons which contain abundant fossil remains should also be employed to check for lithosympatric and lithoallopatric occurrences of key taxa. Lumping of specimens which come from a number of fossiliferous horizons or geographically isolated exposures which are from a similar lithostratigraphic unit (arbitrary sampling) tends to obscure relations and boundaries and lends confusion to age relations over broad geographic areas.

History of Upper Wind River Formation Biostratigraphy

The general historical development of Wind River Formation biostratigraphy is presented in Table 3. However, several key events are briefly reviewed to provide a background and basis for the biostratigraphic zonation which follows.

Osborn (1909) was the first to divide the Wind River Formation into biostratigraphic zones. He (op. cit., Fig. 5, and pp. 43-48; see Fig. 11 this report) recognized two zones, Wind River A and Wind River B, which were, in the modern sense, taxon range zones. He named these zones the Lambdotherium and Bathyopsis zones, respectively. He assumed that Palaeosyops borealis had been recovered from the Bathyopsis zone, although this was uncertain (op. cit., pp. 45 and 48). Although Bathyopsis was the namesake for the upper zone, Osborn reported this genus from the lower Lambdotherium zone as well (op. cit., p. 47). Osborn (op. cit., Fig. 1, pp. 23 and 44), in his "Composite Section of the Tertiary Deposits of the West," suggested that the Bathyopsis zone or Wind River B was correlated, in part, with the upper Huerfano (q.v., Robinson, 1966) and upper unfossiliferous "C" horizon of the "Wasatch of the Bighorn Basin" (q.v., Bown, 1982).

The year following Osborn's biostratigraphic zonation, Granger (1910) revised Osborn's interpretations. He, as did Osborn, divided the formation into two zones. However, his upper zone included both the Lambdotherium and Bathyopsis zones (Fig. 12). The lower zone was a new concept which corresponds to the Lysite Member fauna of Guthrie (1967). This lower zone is not discussed

Table 3. History of Wind River Formation biostratigraphy.

1880	Cope first describes the "Wind River" vertebrate fauna consisting of 19 species of mammals collected by Wortman. Notes presence of Wasatch and Bridger taxa.
1881	Cope amends the Wind River faunal list to include 45 species of vertebrates (three of which are now thought to have been collected in the Bighorn Basin). Compares a faunal list of the Wind River with the Wasatch and Bridger.
1892	Osborn and Wortman begin revision of the Wind River fauna and refer the Wind River Basin fauna to the Bridger.
1899	Matthew (1899, p. 21) indicates "all the sediments of the Wind River Formation are later than the Wasatch and earlier than the Bridger."
1908-1918	Systematic reviews of Wind River Formation taxa are reported in detail by researchers at the American Museum of Natural History and Amherst College.
1909	Osborn suggests that two faunal horizons may be recognized in the Wind River: a lower "*Lambdotherium* zone" (Wind River A) and an upper "*Bathyopsis* zone" (Wind River B).
1910	Granger "corrects" the error of Osborn and notes that two zones are present: a lower, newly recognized zone and an upper zone which includes both zones of Osborn.
1911	Sinclair and Granger describe the Lost Cabin and Lysite Formations, formalizing Granger's 1910 observations.
1929	Osborn recognizes 1909 "error" and presents a chart showing the stratigraphic distribution of important taxa. Records *Palaeosyops* and *Lambdotherium* as occurring together.
1933	Simpson denotes the Wind River as "later lower Eocene, a part of the Eocene between the classic Wasatch and the Bridger," and recognizes the Lysite and Lost Cabin as formations.
1938	Wilmarth recognizes the Lysite and Lost Cabin as faunal zones in the Wind River Formation.
1941	Wood et al. note the lithologic distinctiveness of the Lysite and Lost Cabin members (or formations). Propose Wasatchian and Bridgerian as new provincial time terms. Wasatchian is "based on at least the upper part of the Wasatch group of southwestern Wyoming" and Bridgerian is "based on the Bridger formation of southwestern Wyoming."

Table 3 (continued). History of Wind River Formation biostratigraphy.

	They indicate that, "if technical justification for assigning the Lost Cabin to Wasatchian time is required, it is supplied by the discovery of the La Barge local fauna (q. v., in the Glossary) in the type area of the Wasatch."
1945	Van Houten reviews latest Paleocene and early Eocene mammalian faunas of North America. Provides comprehensive faunal lists for Lysite and Lost Cabin Members. Uses Lysite and Lost Cabin as terms for both faunas and beds.
1948	Tourtelot formalizes and defines Lysite and Lost Cabin Members and provides faunal lists. Tourtelot and Thompson report Bridgerian-like species from the Wind River Formation.
1952	White describes the Wind River Formation fauna from the Boysen Reservoir area. Gazin reviews Wasatchian faunas of southwestern Wyoming and refers to some of these as similar to the Lysite and Lost Cabin in age.
1954	Kelley and Wood review Lysite Member fauna. Morris reviews Cathedral Bluffs Tongue of the Wasatch Formation fauna.
1962	Gazin revises the Wasatchian faunas of southwestern Wyoming in the type area of the Wasatch and refers to the Lostcabinian informally as an age.
1966	Robinson proposes the Gardnerbuttean sugstage of the Wasatchian for the fauna from the upper Huerfano formation, which is similar in concept to the Lostcabinian of the Wind River Formation. He notes two faunal levels in the Lostcabinian faunal level of the Huerfano formation. Discusses many taxa recovered from the Lost Cabin Member.
1967	Guthrie reviews Lysite Member fauna and notes the occurrence of <u>Lambdotherium</u> in upper beds of Lysite Member lithology.
1971	Guthrie reviews Lost Cabin Member fauna. Believes all fossils were recovered from narrow 40 ft. (12 m) interval.
1977	Savage proposes the Wasatchian stage as worldwide in scope and <u>Lambdotherium</u> Concurrent Range zone for Western North America.
1980	Shankler proposes biostratigraphic zonation for the Willwood Formation in the Bighorn Basin. Relates these zones to Wind River Formation as they were proposed by Guthrie.

Table 3 (continued). History of Wind River Formation biostratigraphy.

1982	Stucky and Krishtalka present preliminary faunal lists for two newly discovered fossiliferous horizons in a lithological unit unique from either the Lost Cabin or Lysite Members. Korth discusses occurrence of specimens believed to represent Lambdotherium which were recovered from the Lysite Member.

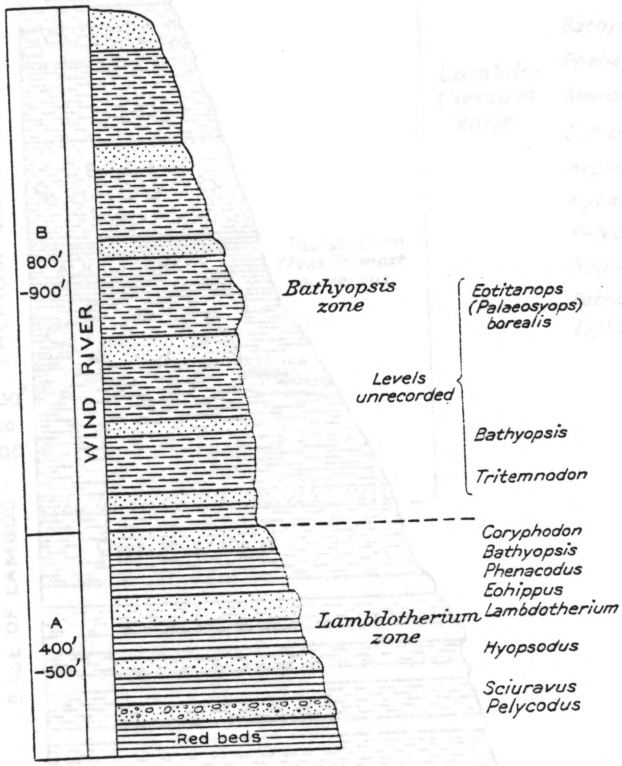

Fig. 11. Osborn's (1909) composite section of the Wind River Formation. Note the suggestion that Palaeosyops borealis and Lambdotherium had non-overlapping ranges.

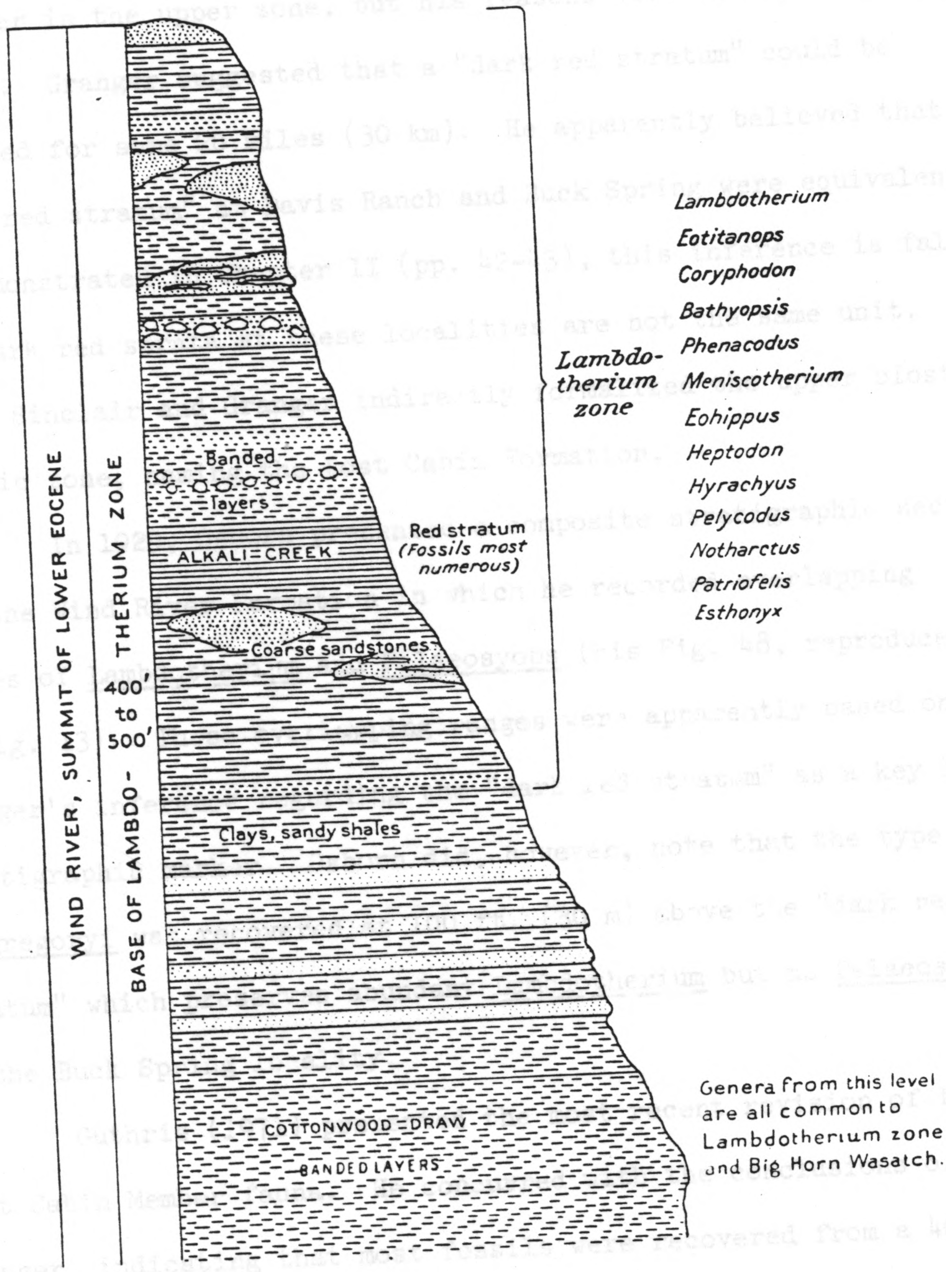

Fig. 12. Granger's (1910) composite section. Note the inference that Palaeosyops borealis and Lambdotherium were recovered from the same stratigraphic interval.

here. Granger believed that Lambdotherium and Palaeosyops occurred together in the upper zone, but his reasons were not specifically stated. Granger suggested that a "dark red stratum" could be followed for some 20 miles (30 km). He apparently believed that the "dark red stratum" at Davis Ranch and Buck Spring were equivalent. As demonstrated in Chapter II (pp. 42-43), this inference is false; the dark red strata at these localities are not the same unit. In 1911, Sinclair and Granger indirectly formalized the upper biostratigraphic zone, naming the Lost Cabin Formation.

In 1929, Osborn presented a composite stratigraphic section for the Wind River Formation in which he recorded overlapping ranges of Lambdotherium and Palaeosyops (his Fig. 48, reproduced here in Fig. 13). These overlapping ranges were apparently based on Granger's inference regarding the "dark red stratum" as a key lithostratigraphic marker. Osborn did, however, note that the type of P. gregoryi was recovered at 100 ft. (30 m) above the "dark red stratum" which preserves abundant Lambdotherium but no Palaeosyops, at the Buck Spring locality.

Guthrie (1971) presented the most recent revision of the Lost Cabin Member fauna. He concurred with the conclusions of Granger, indicating that most fossils were recovered from a 40 ft. (12 m) interval of strata. More recently, Korth (1982) has followed previous workers but suggests that the Lost Cabin Member localities occur in a much thicker interval than Guthrie believed. His stratigraphic interpretations are based on elevation and bed attitudes and do not concur with the biostratigraphic record.

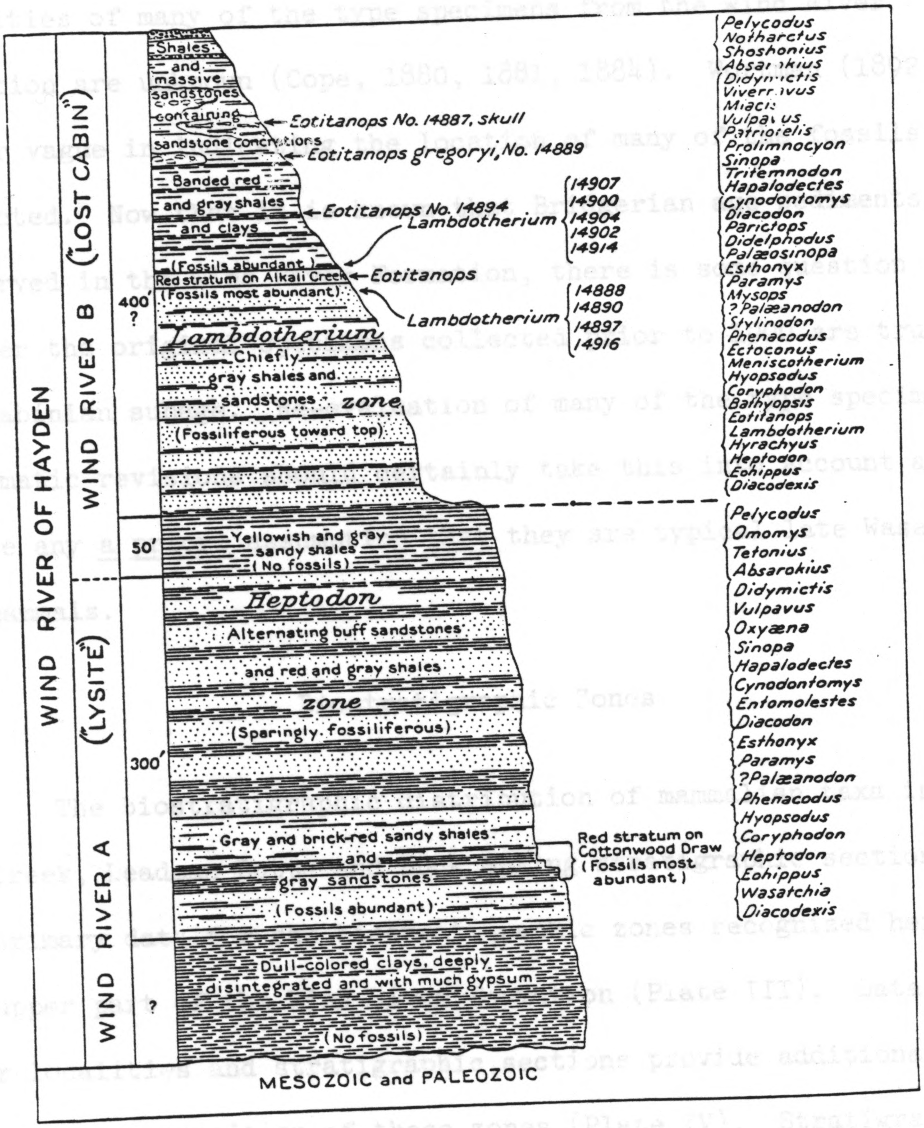

Fig. 13. Osborn's (1929) composite section of the Wind River Formation. Note the overlapping ranges of Palaeosyops (=Eotitanops) borealis and Lambdotherium. These overlapping ranges were presumably based on the correlation of the "dark red stratum" of Granger (1910).

One final note is of some historical importance. The actual localities of many of the type specimens from the Wind River Formation are unknown (Cope, 1880, 1881, 1884). Wortman (1892) was rather vague in indicating the location of many of the fossils he collected. Now that it is known that Bridgerian age sediments are preserved in the Wind River Formation, there is some question as to whether the original specimens collected prior to 1900 are truly of Lostcabinian subage. Re-evaluation of many of the type specimens in systematic revisions should certainly take this into account and ignore any a priori assumption that they are typical late Wasatchian Age mammals.

Biostratigraphic Zones

The biostratigraphic distribution of mammalian taxa in the Red Creek, Deadman Butte and Buck Spring stratigraphic sections form the primary data for the biostratigraphic zones recognized here in the upper part of the Wind River Formation (Plate III). Data from other localities and stratigraphic sections provide additional support to the recognition of these zones (Plate IV). Stratigraphic and taphonomic data, locality name synonymies and collection methods are given in Appendix B. The systematics of the mammalian fauna and a list of lower vertebrate taxa in UCM collections is provided in Chapter V. The biostratigraphic zones are proposed only for the upper part of the Wind River Formation in the northeastern Wind River Basin. Future field studies may indicate that these zones can be extended elsewhere.

Lambdotherium range zone (=Lambdotherium zone)

Reference sections: Red Creek, Deadman Butte and Buck Spring stratigraphic sections (Chapter II, Appendix A). See Granger (1910), Osborn (1929), Tourtelot (1948) and Keefer (1965a) for more information on the Buck Spring stratigraphic section.

Key localities: Buck Spring "dark red stratum" (Guthrie's Locality 3, UCM Loc. 81029); Wolton locality (Guthrie's Locality 2); UCM Locs. 79039 and 79045 in the Red Creek stratigraphic section; UCM Locs. 80062, 80089, and 81008 in the Deadman Butte stratigraphic section; and UCM Loc. 80063 located north and east of Arminto.

Lower boundary: Lowest occurrence of Lambdotherium popoagicum; presently recognized at unit 8, Red Creek stratigraphic section, approximately 60 ft. (18 m) above Wind River Formation contact on Mesozoic strata.

Upper boundary: Lowest occurrence of Palaeosyops borealis; presently recognized at the 140 ft. (43 m) level in Deadman Butte stratigraphic section, which is 60 ft. (18 m) above last known occurrence of Lambdotherium popoagicum. Osborn's (1929) observations suggest that P. borealis occurs at a level 100 ft. (30 m) above "dark red stratum" of Granger (1910) in the Buck Spring area. Lowest occurrence of P. borealis in Red Creek stratigraphic section is at unit 61, approximately 200 ft. (61 m) above last documented occurrence of L. popoagicum.

Taxa restricted to this zone: *Loveina zephryi*; Viverravinae?, gen. et sp. nov.; *Hyopsodus walcottianus*; *Lambdotherium popoagicum*.

Characteristic taxa: *Palaeosinopa* spp.; *Microsyops* sp., cf. *M. scöttianus*; *Uintasorex* sp., cf. *U. parvulus*; *Notharctus* sp., cf. *N. venticolus*; *Coryphodon* sp.; *Esthonyx acutidens*; *Hyopsodus paulus*; *H. wortmani*; *Phenacodus* spp.; *Hyracotherium* spp.; *Lambdotherium popoagicum*; *Heptodon ventorum*; *Paramys* spp.; *Knightomys* spp.; *Pauromys* sp.

Apparent extinctions: *Loveina zephryi*; *Thryptacodon loisi*; *Hyopsodus walcottianus*; *Lambdotherium popoagicum*.

Apparent first local appearances: *Scenopagus* spp.; *Nyctitherium* sp., cf. *N. serotinum*; *Loveina zephryi*; *Alveojunctus* sp.; *Uintasorex* sp., cf. *U. parvulus*; *Shoshonius cooperi*; *Absarokius witteri*; cf. *Orohippus* sp.; *Bunophorus sinclairi*; *Diacodexis olseni*; *Pauromys* sp.

Zone recognition: *Lambdotherium popoagicum* is usually one of the first taxa recovered by surface prospecting from a fossiliferous horizon. This taxon and remains of *Coryphodon* sp., *Palaeosinopa* spp., *Hyopsodus paulus*, *Hyracotherium craspedotum*, and *Heptodon ventorum* are usually diagnostic.

Comments: Maximum thickness of the *Lambdotherium* zone is approximately 140 ft. (43 m, base not exposed) in the Deadman Butte section and 300 ft. (90 m) in the Red Creek stratigraphic section, including an unfossiliferous sequence. Lithology plays no role in the recognition of this biostratigraphic unit.

To the best of my knowledge, Locality 48FR76 (White, 1952) is the only Wind River Formation locality where Lambdotherium and Palaeosyops may occur within the same fossiliferous horizon. White (p. 204) indicates the fossils from this locality came from "a small area of banded red and greenish clays with local concretionary zones." Thus White does not provide sufficient data to assess this possible lithosympatric occurrence of the two genera. Fossil preservation is nearly identical for the two genera, suggesting that they did come from the same fossiliferous horizon. If this is true, 48FR76 would be within the Palaeosyops borealis assemblage zone.

White's (1952) Localities 48FR75 and 48FR78 occur in the Lambdotherium zone because of the presence of Lambdotherium. White also reports Hyopsodus powellianus (=H. walcottianus) from 48FR75. 48FR80 probably also could be included in the Lambdotherium zone because of the presence of Meniscotherium, but the stratigraphic range of this genus is not well known. Meniscotherium has been found only in the Boysen Reservoir area (Muddy Creek of Granger, 1910). Its absence in the Red Creek-Deadman Butte area is of paleobiogeographic or biostratigraphic interest. Most localities in the Wind River Formation reported by Keefer (1965a) are apparently also in the Lambdotherium zone. Olsen (in Sinclair and Granger, 1911) recovered a fauna with Lambdotherium and no Palaeosyops, Hyrachyus or Trogosus from the Beaver Divide area in the southern part of the Wind River Basin.

Guthrie (1967) and Korth (1982) have reported Lambdotherium from the Lysite Member. Neither Wallace (1980) nor I have examined the tooth identified by Guthrie. The two teeth identified as _Lambdotherium_ by Korth (1982) are M3L talonid fragments of an equid (see Chapter V discussion of _L. popoagicum_).

Guthrie (1971) reports _Homogalax_ from the Lost Cabin Member. Of the two specimens figured, CM 22389 is an upper molar of _Hyracotherium craspedotum_ (prominent metaconule and paraconule; bunodonty), and CM 22390 is a composite specimen of a molar of _H. craspedotum_ and _H. vasaccience_ (hypolophid not complete, twinned metaconid). Froelich and Raser (1981) have also questioned the occurrence of _Homogalax_ in the Lost Cabin Member.

Korth (1982) reported that Guthrie's (1971) Locality 2 (Wolton) was between 125 m and 250 m stratigraphically above Locality 1 (Davis Ranch). He based this interpretation on present elevation and attitudes of strata at these two beds. The fauna from Locality 2 suggests these exposures are in the _Lambdotherium_ zone, whereas Locality 1 is used to define the _Palaeosyops borealis_ assemblage zone. Structural data (Chapter II) suggests that Locality 2 may be lower in the section than Locality 1.

UCM Loc. 80083 could not directly be placed in the Red Creek stratigraphic section because of its geographic position on the west side of Red Creek. This fossiliferous horizon may represent a lower biostratigraphic unit because of its mammalian fauna and probable lower position in the lower gray sequence.

Palaeosyops borealis assemblage zone

(Palaeosyops borealis zone)

Reference sections: Red Creek, Deadman Butte, Buck Spring, Rainbow Butte and Sullivan Ranch stratigraphic sections. See Osborn (1929) for record of Palaeosyops gregoryi (?=P. borealis, see Wallace, 1980; Bown, 1982) in the Buck Spring type area.

Key localities: UCM Locs. 79040 and 80061 in the Red Creek Stratigraphic section; UCM Locs. 80090 and 81010 in the Deadman Butte stratigraphic section; Davis Ranch localities (Locality 1 of Guthrie, 1971; Sullivan Ranch locality on CM specimen labels; 5 mi. North and West of Arminto on PU specimen labels; UCM Locs. 79041, 79042, 79043, 81016-81028, 81048); Rainbow Butte (UCM Loc. 80065).

Lower boundary: Lowest occurrence of Palaeosyops borealis (and/or P. gregoryi), Trogosus sp., Microsyops lundeliusi, Antiacodon and/or possibly Hyrachyus sp., cf. H. eximius presently recognized at 140 ft. (43 m) above "dark red stratum" at the Buck Spring locality in the type area of the Lost Cabin Member (Osborn, 1929). In the Red Creek section, P. borealis, Trogosus sp. and Hyrachyus sp., cf. H. eximius first occur lithosympatrically at unit 61 (UCM Loc. 79040), approximately 200 ft. (60 m) above last occurrence of L. popoagicum. Unit 56 (UCM Loc. 80061) is the lowest fossiliferous horizon in the Red Creek section that is included in this zone.

Upper boundary: Not preserved, upper strata in the Red Creek, Deadman Butte, Buck Spring, Rainbow Butte and Davis Ranch stratigraphic sections are either poorly exposed or covered by vegetation or

Quaternary gravel. Based on data of Tourtelot and Thompson (1948) and Wallace (1980) may be placed at first occurrence of P. huerfanensis. Other potential taxa which do not occur as far as known in the Wind River Formation in the northeastern Wind River Basin but have restricted biostratigraphic ranges in southwestern Wyoming include Omomys, Anaptomorphus, Bathyopsis middleswarti, Microsus, Sciuravus and Tillomys.

Taxa restricted to this zone: Ectocion superstes; Palaeosyops borealis; Selenaletes scopaeus; Antiacodon vanvaleni.

Characteristic taxa: Scenopagus spp.; Uintasorex sp., cf. U. parvulus; Microsyops sp., cf. M. scottianus; M. lundeliusi; Shoshonius cooperi; Notharctus sp., cf. N. robinsoni; Esthonyx acutidens; Trogosus sp.; Hyopsodus spp.; Phenacodus primaevus; Hyracotherium vasaccience; Palaeosyops borealis; Heptodon ventorum; Selenaletes scopaeus; Hyrachyus sp., cf. H. eximius; Diacodexis spp.; Bunophorus sinclairi; Antiacodon spp.; Paramys spp.; Knightomys spp.; Pauromys sp.

Apparent extinctions: Palaeosinopa spp.; Absarokius spp.; Copelemur spp.; Hyopsodus wortmani; Phenacodus vortmani; Ectocion superstes; Esthonyx acutidens; Selenaletes scopaeus; Bunophorus spp., Diacodexis spp.; Antiacodon vanvaleni; Coryphodon sp.

Apparent first local appearances: Palaeictops sp., cf. P. bridgeri; Pantolestes sp., cf. P. longicaudus; Microsyops lundeliusi; cf. Huerfanius sp.; cf. Smilodectes sp.; Trogosus sp.; Mesonychidae, sp. indet.; Hyopsodus sp., cf. H. minusculus; Hyopsodus sp. A;

Ectocion superstes; Palaeosyops borealis; Helaletes nanus; Selenaletes scopaeus; Hyrachyus sp., cf. H. eximius; Antiacodon spp.; Helohyus plicodon; Palaeanodonta sp. A; ?Thisbemys sp.

Zone recognition: Large mammals usually recovered in the first surface collection from a fossiliferous horizon in this zone include P. borealis, Trogosus sp. and Hyrachyus sp., cf. H. eximius. These taxa plus any taxa listed under first local appearances and the lack of Lambdotherium popoagicum is also diagnostic.

Comments: Hyrachyus appears not to be present in the Lambdotherium zone. Dawson (CM, oral communication, 1982) found associated isolated teeth of Hyrachyus in the upper levels of the Buck Spring area.

Guthrie's (1971) Locality 4 is of some interest. Most specimens were recovered from a gray unit that yielded isolated teeth of small mammals and lower vertebrate materials. According to Guthrie (p. 4), this locality occurs at nearly the same level as the "dark red stratum" at Buck Spring. The assemblage from Locality 4 (Microfauna locality on CM specimen labels) is more like the fauna from the Palaeosyops borealis zone than the Lambdotherium popoagicum zone. Helaletes, Orohippus and Notharctus sp., cf. N. robinsoni are known from this locality. The specimens do not compare well with specimens from the "dark red stratum" and have a progressive flavor. This locality deserves future attention. Whether it is stratigraphically equivalent or not, the fauna from this locality should prove to be of importance. Guthrie's (1971) faunal list is a composite of specimens from both the Lambdotherium and Palaeosyops _borealis_ zones; many of the species are not lithosympatric in the Wind River Formation (Plate IV).

White's (1952) localities 48FR65 and 48FR79 contain _Palaeosyops borealis_ in their assemblages and are thus referrable to the _Palaeosyops borealis_ zone. The type of _Microsyops lundeliusi_ was also recovered from 48FR65.

Tourtelot and Thompson (1948) report _Eotitanops_ (=_P. borealis_) from the lower part of the Wind River Formation in the Boysen Reservoir area. _Heptodon_? (=_Helaletes nanus_) and _Coryphodon_ were also recovered. Above these occurrences, _P. huerfanensis_ (see Wallace, 1980) and _Hyrachyus_ are reported. These occurrences suggest the possibility of defining a biostratigraphic zone above the _Palaeosyops borealis_ zone in the Wind River Formation.

The Davis Ranch stratigraphic section fossiliferous horizons (all included in Guthrie's Locality 1) represent the most extensive collection of fossil vertebrates from any area of exposure within the _Palaeosyops borealis_ zone. Literally thousands of specimens of approximately 75 mammalian species are represented. Lower vertebrates are also abundant but have not as yet been studied in detail. Most mammal species are represented by at least ten specimens, and some are represented by as many as a hundred. Fortunately, most fossils come from a single fossiliferous horizon, the "maroon shale" or "dark red stratum" (Granger, 1910; Guthrie, 1971). Preservational characteristics of fossils can be used to determine the general level from which undocumented fossils were recovered (see Appendix B).

Although many of the species recorded here are represented by only one or two specimens, their lack of occurrence in the

Lambdotherium zone, taken together, would appear to be significant. More importantly, many of the taxa characteristic of the _Palaeosyops borealis_ zone are also characteristic of faunas which have been described as either transitional between the Wasatchian and Bridgerian (Upper Huerfano fauna of Robinson, 1966; Cathedral Bluffs Tongue fauna of Morris, 1954; Gazin, 1962; and West, 1973) or as early Bridgerian (McGrew and Sullivan, 1971; West, 1973; Gazin, 1976; and Bown, 1982). This is the subject of the next chapter, which suggests that the _Palaeosyops borealis_ zone of the Wind River Formation be included in the Bridgerian Land Mammal Age (Gardnerbuttean subage) or the earliest middle Eocene.

CHAPTER IV

THE WASATCHIAN-BRIDGERIAN LAND MAMMAL AGE BOUNDARY

North American Land Mammal Ages were originally defined for continental strata by Wood et al. in 1941. They proposed eighteen provincial time terms which divided the Cenozoic record of mammalian faunas from rock units scattered throughout western North America. This new terminology served to clarify correlations within North America without a direct reliance on terms defined outside of this continent.

The Wasatchian and Bridgerian Land Mammal Ages were based on the vertebrate faunas of the Wasatch and Bridger Formations of southwestern Wyoming. Since the original definitions of these ages, additional discoveries and revisions of fossil mammal faunas have been made. Several of these faunas are intermediate between the Wasatchian and Bridgerian (Cathedral Bluffs Tongue of the Wasatch Formation fauna [Morris, 1954; Gazin, 1962; West, 1973a; West and Dawson, 1973], New Fork Tongue of the Wasatch Formation fauna [Gazin, 1952, 1962; West, 1973], and upper Huerfano Formation fauna [Robinson, 1966]). More typical late Wasatchian faunas (LaBarge and Dad local faunas [Gazin, 1952, 1962], upper Willwood Formation fauna [Schankler, 1980 , and lower Huerfano Formation fauna Robinson, 1966]), and more typical Bridgerian faunas (Lower Bridger Formation faunas [McGrew and Sullivan, 1970; West, 1973], Aycross Formation fauna

[McKenna, 1980; Eaton, 1980; Bown, 1982]) have also been described. The Almagre and Largo faunas of northwestern New Mexico, previously thought by some to be late Wasatchian in age (e.g., Gingerich and Simons, 1977), have been shown to be of middle Wasatchian age (Lucas et al., 1981).

Classically, the Wasatchian has been divided into early, middle and late units; the Graybullian, Lysitean and Lostcabinian, respectively. The Graybullian is based on the lower Willwood Formation fauna of the Bighorn Basin and the Lysitean and Lostcabinian are based on the Lysite and Lost Cabin Member faunas of the Wind River Formation of the Wind River Basin. Robinson (1966) used the term Gardnerbuttean for the upper Huerfano Formation fauna, which he regarded as latest Wasatchian. Savage (1977) has recently suggested that the Wasatchian "stage" could be recognized worldwide. He also defined the Lambdotherium concurrent range zone as a recognizeable unit throughout western North America. Bown (1979) and Schankler (1980) have, in part, abandoned the subdivisions of the Wasatchian in the Willwood Formation, substituting detailed biostratigraphic data. Gingerich and Simons (1977) have used the notharctid primates to subdivide the Wasatchian.

Matthew (1909) divided the Bridger Formation into five units: Bridger A, B, C, D and E. Wood (1934) described the Twin Buttes member of the Bridger Formation for Bridger A and B, and the Black's Fork member of the Bridger Formation for Bridger C and D. Gazin (1976) has referred to Matthew's Bridger A and B as lower Bridger, and Matthew's Bridger C and D as upper Bridger. Bridger E is not very fossiliferous (Gazin, 1976).

Despite the increase in knowledge of the Wasatchian and Bridgerian age faunas, the Wasatchian-Bridgerian boundary has not been well defined. The recognition of the Lambdotherium range zone and the Palaeosyops borealis assemblage zone in the upper part of the Wind River Formation suggests several alternatives for placing this boundary. Mammalian faunas homotaxic with these zones are discussed below. Comparisons of these faunas are based primarily at the generic level, because of the varying taxonomic agreement among researchers at the specific level. The genus seems to be the most objective taxonomic rank. Genera common throughout the late Wasatchian and early Bridgerian and genera that are poorly studied or represented are not generally used or discussed. Plate V lists the generic content of the better represented faunas. The geographic position of these faunas is shown in Fig. 14.

Southwestern Wyoming

LaBarge fauna of the Wasatch Formation--The LaBarge fauna reported by Gazin (1952, 1962) consists of approximately 35 genera of mammals which were recovered from an approximate 100 ft. (30 m) interval. The fauna correlates well with the Lambdotherium zone fauna of the Wind River Formation but may be slightly older. This is suggested by the presence of Lambdotherium popoagicum and possibly by Meniscotherium, and by the general lack of genera that are first appearances in the Palaeosyops borealis zone of the Wind River Formation. Hexacodus is not known from the Wind River Formation and is rare elsewhere in northern Wyoming, suggesting that this genus was

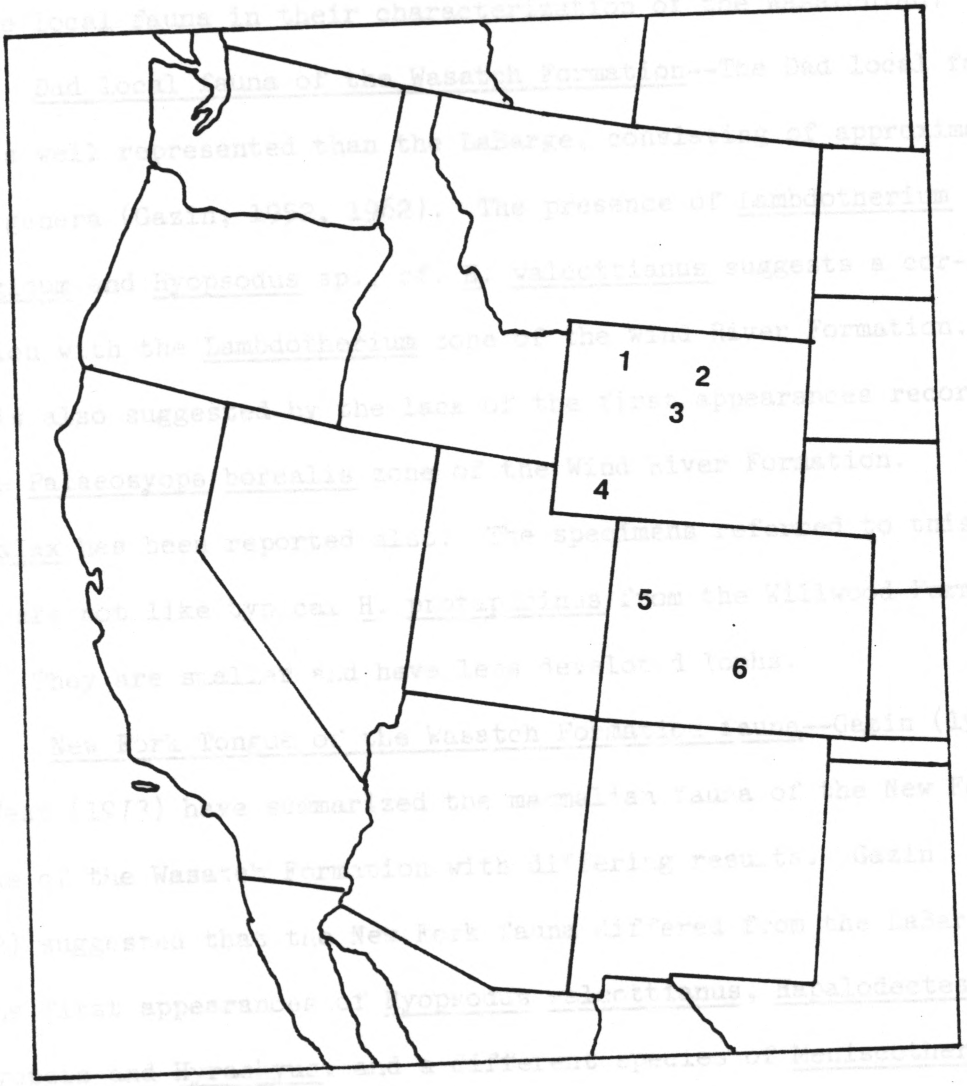

Fig. 14. Map of southwestern North America showing the location of late Wasatchian and early Bridgerian fossil vertebrate localities discussed in the text. Key to localities: 1) Bighorn Basin; 2) Powder River Basin; 3) Wind River Basin; 4) Southwestern Wyoming; 5) Piceance Basin; 6) Huerfano Basin.

biogeographically restricted. Wood et al. (1941) included the LaBarge local fauna in their characterization of the Wasatchian.

Dad local fauna of the Wasatch Formation--The Dad local fauna is less well represented than the LaBarge, consisting of approximately 20 genera (Gazin, 1952, 1962). The presence of Lambdotherium popoagicum and Hyopsodus sp., cf. H. walcottianus suggests a correlation with the Lambdotherium zone of the Wind River Formation. This is also suggested by the lack of the first appearances recorded in the Palaeosyops borealis zone of the Wind River Formation. Homogalax has been reported also. The specimens referred to this genus are not like typical H. protapirinus from the Willwood Formation. They are smaller and have less developed lophs.

New Fork Tongue of the Wasatch Formation fauna--Gazin (1962) and West (1973) have summarized the mammalian fauna of the New Fork Tongue of the Wasatch Formation with differing results. Gazin (1962) suggested that the New Fork fauna differed from the LaBarge by the first appearances of Hyopsodus walcottianus, Hapalodectes, Bathyopsis and Hyrachyus, and a different species of Meniscotherium, M. chamense. He noted that the species of Microsyops, Notharctus, Prolimnocyon and Bunophorus had "evolved more appreciably" than the LaBarge species. In general, the fauna reported by Gazin closely resembles the Lambdotherium zone fauna of the Wind River Formation. The important exception is the occurrence of Hyrachyus, a genus apparently restricted to the Palaeosyops borealis zone in the Wind River Formation. Data provided by Gazin (1962) is not sufficient to determine whether Hyrachyus occurred in either lithosympatry or lithoparapatry with the taxa typical of the Lambdotherium zone of the Wind River Formation.

West (1973a) divided the New Fork Tongue into two facies, a Western Facies and an Arkosic Facies, which intertongue. West reported the mammalian fauna according to exposures, some of which represented collections from a single fossiliferous horizon, whereas others were from sequences of strata 200 ft. (60 m) thick. Localities in the Western Facies contain approximately 25 mammalian genera. All except Omomys are typical of the Lambdotherium zone of the Wind River Formation and include both Lambdotherium popoagicum and Meniscotherium. None of the first appearances of the Palaeosyops borealis zone are reported.

The Arkosic Facies, however, contains genera and species typical of both the Lambdotherium zone and Palaeosyops borealis zone of the Wind River Formation. Two localities from which mammals were recovered are reported, Steele Butte Breaks (BS-1) and East Fork Rim (BS-2). Both of these localities represent 200 ft. (60 m) of stratigraphic section, and it is not known which species came from the same fossiliferous horizons (West, 1973a, written communication, 1981). Hyrachyus and Lambdotherium are reported from the Steele Butte Breaks locality and Palaeosyops borealis and Lambdotherium are reported from the East Fork Rim locality. A specimen from the East Fork Rim locality may also record Hyopsodus walcottianus (FMNH, PM 15318), and cf. Trogosus (FMNH, PM 15602) may be present at Steele Butte Breaks. While the biostratigraphic range relations of any of these taxa is presently beyond proof at these localities, the fauna is of considerable interest. These localities could represent a situation similar to that recorded by White (1952) for locality 48FR76 in the Wind River Formation of possible overlapping ranges or a situation similar to that recorded in the Buck Spring and Deadman Butte stratigraphic sections of the Wind River Formation where _Hyrachyus_ and _Palaeosyops borealis_ apparently do not overlap with _Lambdotherium_ in 100 ft (30 m) of section. These two localities represent an opportunity to test the validity and possible extension of the _Lambdotherium_ and _Palaeosyops borealis_ zones.

Cathedral Bluffs Tongue of the Wasatch Formation fauna--Morris (1954), Gazin (1962, West (1973a) and West and Dawson (1973) have reported the mammalian fauna of the Cathedral Bluffs Tongue of the Wasatch Formation, which consists of approximately 20 genera of mammals. Neither _Lambdotherium_ nor _Hyopsodus walcottianus_ are known from the Cathedral Bluffs fauna. Genera recorded from the _Palaeosyops borealis_ zone fauna of the Wind River Formation as well as the Cathedral Bluffs fauna include _Trogosus_, _Palaeosyops_, _Hyrachyus_ and _Antiacodon_. _Palaeosyops_ is, however, represented by a different larger species, _P. huerfanensis_ (Wallace, 1980). Important genera in the Cathedral Bluffs fauna not represented in the _Palaeosyops borealis_ zone fauna include _Omomys_, _Anaptomorphus_, _Hexacodus_ and _Sciuravus_. The Cathedral Bluffs Tongue fauna would appear to be younger than the _Palaeosyops borealis_ zone fauna of the Wind River Formation. It may correlate with the horizon in the Wind River Formation where Tourtelot and Thompson (1948) report _P. huerfanensis_, and probably correlates with the upper Huerfano Formation (Robinson, 1966).

Lower Bridger Formation fauna--McGrew and Sullivan (1970), West (1973a) and Gazin (1976) have discussed the mammalian fauna of approximately 60 genera of mammals from the lower Bridger Formation. There is no doubt that this fauna is younger than all previously discussed faunas. McGrew and Sullivan (1970) provide excellent biostratigraphic data for 35 fossiliferous horizons in Bridger A. The fauna includes Sciuravus, Omomys, Uintanius, Anaptomorphus and Microsus, which are not known in the Wind River Formation. Otherwise, all genera reported by them (1970) are probably represented in the Palaeosyops borealis zone of the Wind River Formation (i.e., if cf. Washakius and cf. Smilodectes are correctly referred in the Wind River sample). Specific differences are important; they report Bathyopsis middleswarti and Palaeosyops fontinalis (=P. paludosus, see Wallace, 1980). Typical Wasatchian genera of the Palaeosyops borealis zone are absent in this Bridgerian sample--Esthonyx, Ectocion, Coryphodon, Hyracotherium, Diacodexis and Bunophorus.

The lower Bridger Formation fauna from the New Fork-Big Sandy area is similar to the Bridger A fauna (West, 1973a). The fauna differs primarily in the diversity of small mammals which were recovered by the use of screen washing. Important genera not known in the Bridger A fauna include Thinocyon, Tillomys, Taxymys, Reithroparamys, Helohyus and Diacodexis. Diacodexis is the only genus recovered which has been generally thought to be restricted to the Wasatchian.

Gazin's (1976) Lower Bridger sample is based primarily on the collections of the USNM, and includes Matthew's (1909) Bridger A and Bridger B fauna. Genera that are well represented in addition to those reported by both West and McGrew and Sullivan include *Tillodon*, *Ischyrotomus*, *Harpagolestes*, *Limnohyops* and *Parisectilophus*. Other genera are either too poorly known or potentially have closely related sister groups in the Wind River Formation (*Entomolestes*, *Thinocyon*, *Limnocyon*, *Machaeroides*, *Synoplotherium*, *Metacheiromys* and *Tetrapassalus*, see Chapter III).

Bighorn Basin, Wyoming

Recent studies of Schankler (1980) in the Willwood Formation and Bown (1982) in the Aycross Formation of the Bighorn Basin suggest a faunal relationship with the *Lambdotherium* and *Palaeosyops borealis* zones of the Wind River Formation.

Schankler (1980) listed approximately 25 genera of mammals in what he defined as the Upper *Heptodon* Range Zone of the Willwood Formation. The generic composition of Schankler's Upper *Heptodon* Range Zone fauna is nearly identical to the *Lambdotherium* range zone fauna of the Wind River Formation. Species differences appear to be of either paleobiogeographic, paleoecologic and/or time importance. Schankler reports that the common species of *Lambdotherium* is *L*. *primaevum* (=*L*. *popoagicum*, see Wallace, 1980), and that *Esthonyx* is represented by *E*. *bisulcatus* and *E*. *acutidens*. *E*. *bisulcatus* is not known from the *Lambdotherium* zone of the Wind River Formation. The only genus reported by Schankler that is not certainly known from the *Lambdotherium* zone is *Megalesthonyx*. Schankler's sample lacks genera known from the *Palaeosyops borealis* zone of the Wind River Formation including *Palaeosyops*, *Trogosus*, *Hyrachyus*, *Selenaletes*, *Antiacodon* and others. It could be slightly older than the Lambdotherium zone fauna and may correlate with the LaBarge fauna of the Wasatch Formation (Gazin, 1962).

Bown (1982) has presented a faunal list for the Aycross Formation of the Absaroka Range. He records 40 mammalian genera from 28 localities. These localities are presumably distributed over a stratigraphic interval, but each is a fossiliferous horizon. Typical Wasatchian genera are absent, including Ectocion, Coryphodon, Hyracotherium, Lambdotherium, Diacodexis and Bunophorus. Genera common with the Palaeosyops borealis zone of the Wind River Formation include Aycrossia, Trogosus, Palaeosyops, Hyrachyus and Antiacodon. A large species of Palaeosyops is, however, represented from one locality: P. fontinalis (?=P. paludosus). Wallace (1980) has suggested that the Eotitanops borealis specimen reported by Bown (1982) may represent either Eotitanops minimus (referred to a new genus by Wallace) or P. borealis. Important genera not known from the upper part of the Wind River Formation include Omomys and Gazinius. Localities D-1018 and D-1033 compare remarkably well with the fauna from UCM Loc. 79040 of the Palaeosyops borealis zone of the Wind River Formation. The Aycross Formation fauna would appear to be younger than the fauna from the Palaeosyops borealis zone of the Wind River Formation. It possibly could correlate with the Palaeosyops borealis zone and the zone in the Wind River Formation where Tourtelot and Thompson (1948) recovered P. huerfanensis.

McKenna (1980) and Eaton (1980) have also reported faunas from the Aycross Formation which compare well with the fauna reported by Bown (1982).

Huerfano Basin, Colorado

Robinson (1966) provided the most recent comprehensive review of the mammalian fauna from the Huerfano Formation of southern Colorado. Gingerich (1979a, 1981b) has discussed some of the primates and horses from this formation. Robinson (1966) originally divided the Huerfano Formation into two faunal levels, the Lostcabinian and the Gardnerbuttean. Robinson and students have recovered a considerable number of specimens from this formation since his review which substantiate his earlier conclusions. Recently he has revised the faunal succession and now recognizes four zones (oral communications, 1981-1982). The lower zone includes his localities VIII, IX and XII (provenience on file in UCM locality file). This fauna is probably Lysitean in age. The lower intermediate zone includes his localities IV, VI and XI (=VIIIa of 1966) which is very similar in composition to the mammalian fauna of the Lambdotherium zone in the Wind River Formation. The upper intermediate zone includes locality VII and the University of Michigan locality, which contains Palaeosyops borealis. The upper zone includes localities I, II, III and V, which were originally used to define the Gardnerbuttean subage (Robinson, 1966). This new faunal zonation conforms with the biostratigraphic data reported in 1966 and in many ways mirrors the faunal zonation proposed for the Wind River Formation.

The lower intermediate zone fauna includes Lambdotherium popoagicum and Hyopsodus walcottianus in abundance. Microsyops lundeliusi, Trogosus, Palaeosyops borealis, Hyrachyus and Antiacodon are absent.

A rather small assemblage of species is associated with P. borealis in the upper intermediate zone, which includes Loveina zephryi, Paramys copei, Viverravus gracilis and Hyopsodus wortmani. The presence of Loveina zephryi represents a discrepancy with the Palaeosyops borealis zone of the Wind River Formation. The rarity of this washakiine primate in either the Wind River or Huerfano Formations and depauperite fauna of the Huerfano upper intermediate zone make comparison difficult. About the only conclusion that can be drawn is that Lambdotherium popoagicum and Palaeosyops borealis are not known to be lithosympatric or lithoparapatric in the Huerfano Formation (see Wallace, 1980).

The fauna from Robinson's (1966) upper zone of the Huerfano Formation, on which he based the Gardnerbuttean, is very well represented. Neither Lambdotherium nor Hyopsodus walcottianus are reported. Taxa in this upper zone which are also known from the Palaeosyops borealis zone and not the Lambdotherium zone in the Wind River Formation include Microsyops lundeliusi, Trogosus, Palaeosyops, Helaletes, Hyrachyus and Antiacodon. Other taxa which may be represented in the Palaeosyops borealis zone include Huerfanius, Mesonyx and Thisbemys. Specific differences for Palaeosyops (P. huerfanensis) and Didymictis (D. vancleveae) are of importance. Eotitanops minimus (referred to a new genus by Wallace, 1980) is not known from the Wind River Formation. If the evolutionary development of P. huerfanensis was isochronous throughout western North America, the horizon from which Tourtelot and Thompson recovered P. huerfanensis in the Wind River Formation would generally correlate with this upper zone fauna of the Huerfano Formation. Gingerich (1979) has recently reported new species of Smilodectes and Notharctus, S. mcgrewi and N. robinsoni, from the upper Huerfano Formation (Locality II) which may be represented in the Palaeosyops borealis zone of the Wind River Formation (see Chapter V, reported as cf. Smilodectes sp. and Notharctus sp., cf. N. robinsoni). Smilodectes gracilis may also be represented at Huerfano Locality I (Gingerich, 1979).

There is no doubt that typical Wasatchian taxa are also known in the upper zone of the Huerfano Formation as Robinson (1966) and McKenna (1976) have shown. These include Esthonyx acutidens and Coryphodon, which are represented in the Palaeosyops borealis zone of the Wind River Formation as well.

Other North American Areas

Debeque Formation, Colorado--Wallace (1980) suggested that lower molars of Lambdotherium and possibly Palaeosyops were glued together in a specimen from the Debeque Formation of western Colorado. As he indicates, the possible Palaeosyops tooth is broken and does not preserve the critical diagnostic morphology for unquestionable identification. Two premolars from the same locality in this formation were, however, assigned to Palaeosyops and Lambdotherium. Allen Kihm (UCM) is currently revising the entire Debeque Formation mammalian fauna. His results should clarify this probable lithosympatric occurrence of Lambdotherium and Palaeosyops. A lower premolar of Palaeosyops is also reported from the Debeque Formation (Wallace, 1980).

"Wasatch" formation, Powder River Basin, Wyoming--Whitmore (in Soister, 1968) reports a lower deciduous premolar of

Lambdotherium along with Coryphodon and Hyracotherium from Pumpkin Buttes in upper strata of the so called "Wasatch" formation of the Powder River Basin. Delson (1971) has demonstrated that the major part of this rock unit is early Wasatchian in age (Graybullian).

Uinta Basin, Wyoming--Burke (1935) reported Lambdotherium from the Powder Wash locality in the Uinta Basin. The fauna from this locality is typically Bridgerian (Gazin, 1958; Dawson, 1968; Szalay, 1969b; Krishtalka, 1976a,b). The specimen of Lambdotherium is an isolated upper molar which is mineralized in a different way than other teeth from the locality and has been abraided by fluvial transport. This tooth is considered an allochthonous element.

Montana--Wallace (1980) reports that specimens that compare favorably with P. huerfanensis and P. borealis were collected from the same stratigraphic level by Alan Tabrum in the Sage Creek Beds of Montana.

British Columbia--Russell (1935) reported Trogosus from coal deposits in British Columbia (see Gazin, 1953).

Ellesmere Island, Canada--Dawson et al. (1975) have reported a mammalian fauna which could be either late Wasatchian or early Bridgerian (West et al., in press). Wallace (1980) suggests that specimens identified as Lambdotherium from this locality may represent a brontotheriid rather than a paleotheriid.

The Wasatchian-Bridgerian Boundary

The boundary between the Wasatchian and Bridgerian Land Mammal Ages should be determined by definition (cf. Wood et al., 1941). The biostratigraphic relations of various late Wasatchian or early Bridgerian age faunas have become sufficiently well known that the boundary may be defined. Several alternatives are presented with a discussion of their advantages and disadvantages.

Wood et al. (1941, pp. 9-10) defined the Wasatchian and Bridgerian Land Mammal Ages as follows:

> Wasatchian age - new provincial time term, based on at least the upper part of the Wasatch group of southwestern Wyoming (modified to Wasatchian series by C. R. Keyes). As a functional term, the typical areas and faunas must be regarded as those of the Bighorn and Wind River basins of Wyoming. The Wasatchian covers the time during which the faunas of the Sand Coulee, Gray Bull, Lysite and Lost Cabin were deposited. If technical justification for assigning the Lost Cabin to Wasatchian time is required, it is supplied by the discovery of the LaBarge local fauna (q.v., in the Glossary) in the type area of the Wasatch. Principal additional correlatives: upper Canyon Largo and lower Huerfano.
> Index fossils: Ambloctonus, Anacodon, Diacodexis, Diacodon, Didelphodus, Heptodon, Homogalax ("Systemodon"), Hyracotherium ("Eohippus"), Lambdotherium, Meniscotherium, Pachyaena, Palaeonictis, genus cf. Paramys, Pelycodus, Prolimnocyon, Teilhardella.
> First appearance: Anaptomorphus, Eotitanops, Hyopsodus, Miacis, Sinopa, Viverravus, Vulpavus.
> Last appearance: Chriacus, Coryphodon, Didymictis, Dissacus, Ectocion, Ectypodus, Esthonyx, Multituberculata, Oxyaena, Palaeosinopa, Phenacodus, Probathyopsis, Psittacotherium.
>
> Bridgerian age - new provincial time term, based on the Bridger formation of southwestern Wyoming (or a redefinition of Bridgerian "series" of C. R. Keyes), or, more specifically, the time of deposition of Bridger A-D, inclusive, with the enclosed faunas.
> Principal correlative: Washakie A with Bridger C + D.
> Index fossils: Apatemys, Helaletes, Helohyus, Homacodon, Hyrachyus affinus, H. princeps, Mysops, Orohippus, Palaeosyops, Patriofelis, Thinocyon, Tillomys, Tillotherium, Uintatherium.
> First appearance: Harpagolestes, Limnocyon, Mesonyx, Notharctus, Paramys (proper), Sciuravus, Telmatherium.
> Last appearance: Vulpavus.
> Characteristic fossils: Hyopsodus, Hyrachyus, Miacis.

Although the upper Huerfano Formation fauna was not included as a principal correlative of the Bridger Formation fauna, they indicated in the glossary that it was early Bridgerian. Of the index fossils listed by Wood et al. for the Wasatchian, Didelphodus, Heptodon, Hyracotherium, Paramys and Pelycodus (=Notharctus, Pelycodus, Copelemur or Cantius, see Gingerich and Haskin, 1981) are known from the Lambdotherium and Palaeosyops borealis zones of the Wind River Formation. Lambdotherium and Meniscotherium are restricted to the Lambdotherium zone. Anaptomorphus is not found associated with Palaeosyops borealis (=Eotitanops) in any fauna known. Among the last appearances, Ectocion is restricted to the Palaeosyops borealis zone and Ectypodus is restricted to the Lambdotherium zone of the Wind River Formation. Neither of these genera are very common and both are artifacts of the fossil record. Ectocion is known from the earlier Wasatchian and Ectypodus is known from both the earlier Wasatchian (Krause, 1982) and later Eocene (Krishtalka and Black, 1975). All other genera listed as last occurrences occur in either both zones of the Wind River Formation or neither zone.

Of the taxa considered diagnostic by Wood et al. (1941) for the Bridgerian, Apatemys is known from the Wasatchian (West, 1973b; Bown, 1979a), Patriofelis and Tillomys probably have ancestral taxa in the Wind River Formation, Huerfano Formation, Willwood Formation and/or Wasatch Formation, Thinocyon may have an ancestral taxon in the Wind River Formation (Chapter V), and Hyrachyus, Helaletes, Helohyus, Trogosus (=Tillotherium) and Palaeosyops are known from the Palaeosyops borealis zone of the Wind River Formation. Of these, only Helohyus has not been reported from the upper Huerfano Formation. Orohippus (as cf. Orohippus sp.) occurs in both zones of the Wind River Formation. Homacodon is apparently restricted to the upper Bridger (Gazin, 1976).

Among the first appearances listed by Wood et al. (1941) for the Bridgerian age, Harpagolestes, Mesonyx and Telmatherium are rare in the lower Bridger Formation, Limnocyon and Mesonyx are probably known from the Palaeosyops borealis zone of the Wind River Formation (see Chapter V), and Paramys and Notharctus are known from both zones of the Wind River Formation, the Huerfano (Robinson, 1966; Gingerich, 1979) and Wasatch (West, 1973) Formations. Sciuravus is not known to occur in any of these formations, and may be of significance in defining part of the Bridgerian.

Savage (1977, p. 439) defined the term Wasatchian as a chronostratigraphic "stage" of worldwide scope and the "Lambdotherium concurrent range zone" for the western interior region of North America. He defined these as:

> the lower limit of the Wasatchian stage is defined by the lowest joint occurrence of the following genera: Hyracotherium, Coryphodon, Haplomyus, Pelycodus, Apatemys, Didelphodus, Palaeosinopa, Prototomus, Viverravus, Miacis, Pachyaena, Hyopsodus, Homogalax, and Diacodexis. The upper limit of the Wasatchian is subjacent to the lowest joint occurrence of Anaptomorphus, Smilodectes, Uintanius, Washakius, Hemiacodon, Mesonyx, Uintatherium, Palaeosyops, Orohippus, Helaletes, Trogosus, Leptotomus, and Homacodon (North American recognition) and is the highest occurrence of Hyracotherium, Esthonyx, Palaeosinopa, Meniscotherium, and Coryphodon (North American and Eurasian recognition). . . . The lower limit of the Lambdotherium zone is defined by the lowest stratigraphic location of the following: Shoshonius, Patriofelis, Hyrachyus, Eotitanops =Palaeosyops , Lambdotherium, Bathyopsis, and Antiacodon. The upper limit coincides with the upper limit of the Wasatchian.

Savage's "Lambdotherium concurrent range zone" was probably based on the faunas in western North America discussed above for the Lost Cabin Member which up to now were based on arbitrary samples from stratigraphic intervals rather than from well documented biostratigraphic records of fossiliferous horizons. The joint occurrences above the upper boundary of the Wasatchian have never been demonstrated to occur within the same fossiliferous horizon. *Lambdotherium* may not overlap in biostratigraphic range with *Palaeosyops*, *Hyrachyus* and *Antiacodon*.

Robinson (1966) used the terms Lostcabinian and Gardnerbuttean for the late and latest Wasatchian, respectively. He referred the Gardnerbuttean subage fauna to the latest Wasatchian primarily on the basis of surviving typical Wasatchian genera (*Coryphodon*, *Hyracotherium*, *Didymictis*, *Bunophorus* and *Diacodexis*). McKenna (1976) added *Esthonyx* to this list and retained the upper Huerfano Formation fauna in the Wasatchian. The Gardnerbuttean subage was also based on the occurrence in the upper Huerfano Formation of typical Bridgerian genera (*Patriofelis*, *Oodectes*, *Mesonyx*, *Trogosus*, *Palaeosyops*, *Helaletes* and *Antiacodon*). The generic composition of the upper Huerfano Formation fauna and the *Palaeosyops borealis* zone of the Wind River Formation fauna are strikingly similar. The upper Huerfano Formation fauna does, however, contain several important occurrences not known in the *Palaeosyops borealis* zone, including *Omomys carteri* (UCM 23499, Loc. II), *Didymictis vancleveae*, *Eotitanops minimus* (referred to a new genus by Wallace, 1980), and *Palaeosyops huerfanensis*. Generic absences of importance in the Huerfano Formation include *Helohyus*, *Ectocion* and *Selenaletes*.

The *Lambdotherium* zone of the Wind River Formation should be used to represent the Lostcabinian subage. The Lostcabinian subage then becomes typified primarily by the presence of

Lambdotherium and Hyopsodus walcottianus. As such the Lostcabinian would also include the upper Heptodon range zone fauna of the Willwood Formation, the LaBarge and Dad local faunas and, in part, the Arkosic Facies and Western Facies of the New Fork Tongue of the Wasatch Formation, the upper horizons of the Debeque Formation, the lower Huerfano Formation and perhaps the upper part of the so called Wasatch Formation of the Powder River Basin.

The faunal composition of the Palaeosyops borealis assemblage zone of the Wind River Formation is in many ways quite similar to the upper Huerfano Gardnerbuttean fauna and the faunas from the Cathedral Bluff and, in part, the Arkosic Facies of the New Fork Tongue of the Wasatch Formation. If the concept of the Gardnerbuttean is emended to include Palaeosyops borealis, as advocated here, I believe that the Gardnerbuttean subage is useful and important in understanding the shift from the Wasatchian to the Bridgerian.

The Gardnerbuttean represents an interval of time of great interest for studying the processes of evolution and ecology in the fossil record. The apparent extinction and immigration of taxa would appear to be tied quite well to the development of the Bridgerian chronofauna. Extinction-origination equilibrium models (see MacArthur and Wilson, 1967; Webb, 1969; Lockley, 1976) do not sufficiently explain the interval, primarily because so many of the taxa that became extinct have either a closely related sister group or a taxon within the same guild among the immigrant taxa. The extinctions seem more allied to the adaptations of these species rather than to a stochastic process. Extinction-origination is probably an epiphenomenon of community interactions.

Boundaries between faunal zones or biochronologic units should be based on well defined and documented stratigraphic occurrences and are probably best placed at the first occurrences of exotic taxa (Repenning, 1967; Tedford, 1970; Woodburne, 1977; Rose, 1981).

The data presently available on late Wasatchian to early Bridgerian faunas suggests several alternative solutions to determining a boundary between these two Land Mammal Ages. Fig. 15 presents the ranges of biostratigraphically important key taxa for western North America through the Wasatchian and Bridgerian as they are currently understood.

The first alternative would place the boundary at the beginning of the Gardnerbuttean as emended above (i.e., including the occurrence of *Palaeosyops borealis*). This boundary would be determined by the first appearances of *Palaeosyops* (also first appearance of Brontotheriidae), *Trogosus*, *Hyrachyus*, *Helaletes*, *Antiacodon*, *Helohyus*, *Pantolestes* and perhaps *Washakius* and *Smilodectes*. The absence of *Lambdotherium* would also be important.

The advantages of this boundary are: 1) the appearance of exotic taxa in conjunction with more primitive taxa is relatively easy to recognize in the fossil record; 2) the immigration of the exotic taxa appears to be nearly synchronous, although it was by no means simultaneous; and 3) the indirect advantage of a shift from "looking for" taxa typical of either the Wasatchian or Bridgerian to actually describing and detailing morphologic variation. The disadvantages to this boundary are: 1) the boundary would apparently not be recognizeable in the rocks on which the Bridgerian and

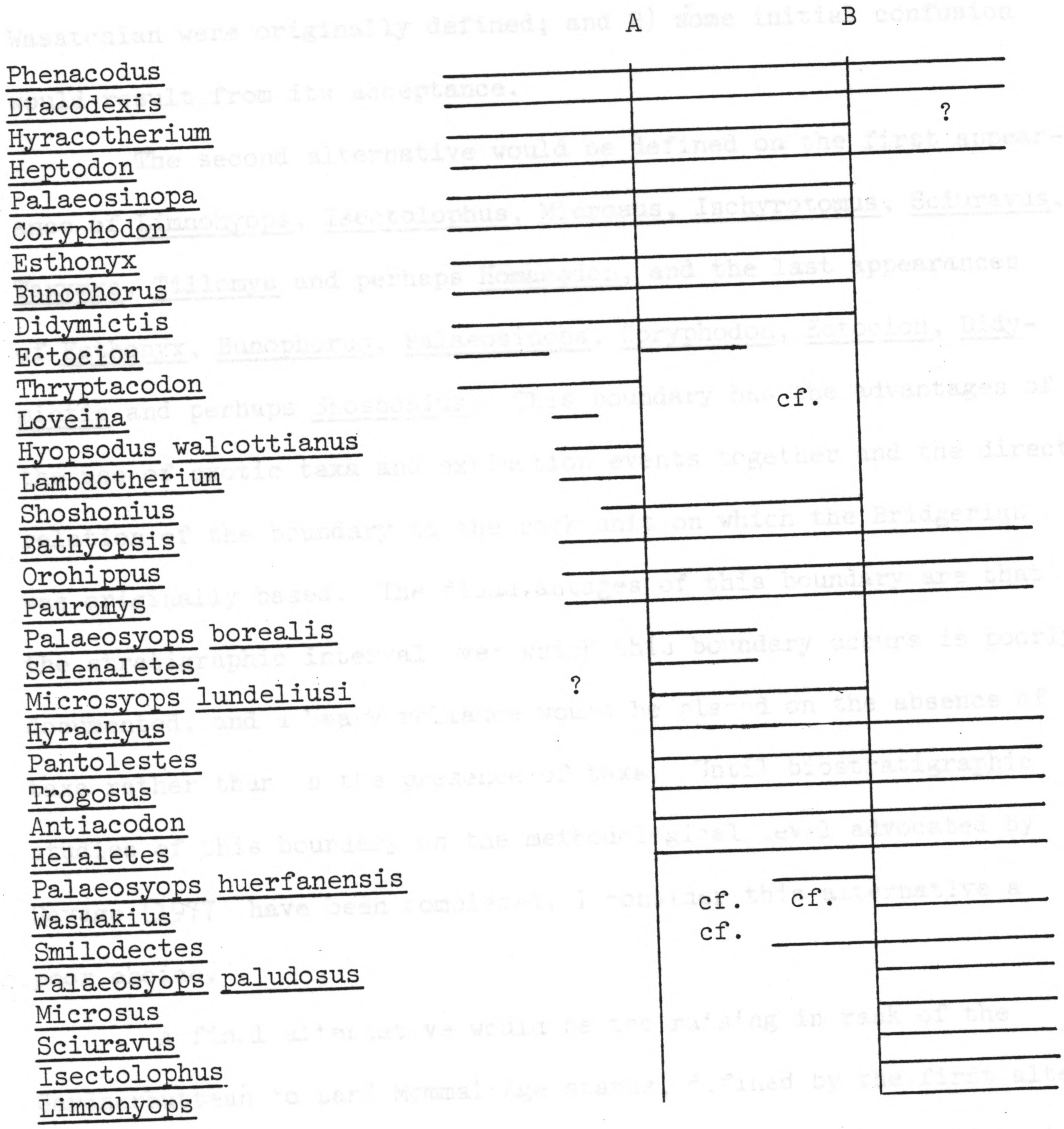

Fig. 15. Biostratigraphic distribution of key taxa from the late Wasatchian through the early Bridgerian. Vertical lines A and B represent alternatives for the definition of the Wasatchian-Bridgerian boundary. See text for discussion.

Wasatchian were originally defined; and 2) some initial confusion would result from its acceptance.

The second alternative would be defined on the first appearance of Limnohyops, Isectolophus, Microsus, Ischyrotomus, Sciuravus, Taxymys, Tillomys and perhaps Homacodon, and the last appearances of Esthonyx, Bunophorus, Palaeosinopa, Coryphodon, Ectocion, Didymictis and perhaps Shoshonius. This boundary has the advantages of the use of exotic taxa and extinction events together and the direct relation of the boundary to the rock unit on which the Bridgerian was originally based. The disadvantages of this boundary are that the stratigraphic interval over which this boundary occurs is poorly documented, and a heavy reliance would be placed on the absence of taxa rather than on the presence of taxa. Until biostratigraphic studies of this boundary on the methodological level advocated by Savage (1977) have been completed, I consider this alternative a poor choice.

A final alternative would be the raising in rank of the Gardnerbuttean to Land Mammal Age status, defined by the first alternative above at its earlier boundary and the second alternative at its later boundary. This would have the advantage of emphasizing the co-occurrence of exotic and primitive taxa, but would de-emphasize the relationships of Gardnerbuttean taxa to either Wasatchian or Bridgerian taxa. In addition, two boundaries would be created instead of one.

It is my opinion that using the first alternative represents the better choice, primarily because this boundary 1) is apparently preserved in several areas; 2) would emphasize the evolutionary patterns of the Bridgerian in general; 3) would shift the paleontological analysis of species to an emphasis on patterns of variation rather than patterns of stability; and 4) would fit well into the modern philosophical foundations of systematic analysis--where derived characteristics or exotic taxa represent the primary basis for establishing relationships.

CHAPTER V

VERTEBRATE FAUNA OF THE UPPER PART OF THE WIND RIVER FORMATION

The fossil vertebrate fauna of the upper part of the Wind River Formation is now recognized to be one of the most diverse of any North American Eocene sequence of strata. Guthrie (1971) listed 77 mammalian species and eight lower vertebrates from the Lost Cabin Member. Recent collecting efforts in both the Lost Cabin Member and the Lower Gray Member have expanded these numbers to approximately 120 mammalian species and nearly half as many lower vertebrates (Plates III and IV). This increase is due to repeated collecting efforts at older localities, the use of underwater screen washing techniques for the recovery of small mammals and lower vertebrates, and the examination of newly discovered fossiliferous horizons in a variety of previously unsampled sedimentary facies.

The fossil vertebrate fauna reported here consists only of those specimens in the University of Colorado Museum collections. Approximately 115 mammalian species are reported, many of which are known from isolated teeth. Several thousand additional specimens from the upper part of the Wind River Formation are now preserved in the vertebrate fossil collections of the American Museum of Natural History, the Carnegie Museum of Natural History, Princeton University Museum and the United States National Museum. Smaller collections are preserved in a number of other institutions. The vertebrate fossil collections from both the Lysite and Lost Cabin Members are in the process of complete revision and analysis (Korth, 1981, 1982; Stucky and Krishtalka, 1982).

The systematic analysis focuses on the mammalian taxa. During the study of previously reported fossil materials, it was recognized that many species with a genus and in some cases specimens within a species were identified on the basis of either size alone or the rock unit from which a fossil was recovered. Details of morphology were often ignored. I have made an attempt to indicate, in most cases, the morphological criteria considered to be of diagnostic value for each species. The morphological characters used are considered to represent hypotheses of character differences between species which represent closely related sister groups. The use of morphological characters results in a more consistent and objective method of identifying the specimens.

It has not been possible to analyze all mammalian taxa in equal detail, either because of the fragmentary nature of some of the specimens, the need for revision of some groups, or my unfamiliarity with some taxa. The treatment of the creodonts and miacine carnivores is tentative. I have, however, identified specimens within these groups as closely as possible to a named taxon on the basis of literature descriptions and my own studies of type specimens, casts, and specimens identified by others. The rodents have been kindly identified by William Korth (1981) and only a faunal list is included here.

The birds are currently being identified by Peter Houde (Howard University). Howard Hutchinson (UCB) is presently studying some of the turtle remains and has kindly allowed me to include a list of the turtles he has identified. The remaining lower vertebrates (fish, amphibians, lizards, snakes and crocodiles) are presently under study and only a preliminary faunal list is provided (Table 4).

Table 4. Lower vertebrate taxa from the Wind River Formation, Red Creek-Deadman Butte area.

- Class Elasmobranchii
  - Order Batoidea
    - Family Dasyatidae
      - *Dasyatus* sp.
- Class Osteichthyes
  - Order Amiiformes
    - Family Amiidae
      - *Amia* sp.
  - Order Lepisosteiformes
    - Family Lepisosteidae
      - Lepisosteidae sp.
  - Order Siluriformes
    - Family Ictaluridae
      - *Astephus* sp.
- Class Amphibia
  - Order Salientia
  - Order Urodela
- Class Reptilia
  - Order Testudinata[1]
    - Family Dermatemydidae
      - *Baptemys tricarinata*
    - Family Kinosternidae
      - *Xenochelys* n. sp.
      - Kinosterninae n. gen.
    - Family Trionychidae
      - *Trionyx s.l.*
      - *Plastomenus*
    - Family Emydidae
      - *Echmatemys* cf. *testudinea*
      - *Echmatemys* sp.
      - Emydid box turtle, n. gen.
    - Family Testudinidae
      - *Hadrianus*
    - Family ?Baenidae
  - Order Sauria
    - Family Teidae
    - Family Aganiidae
      - *Tinosaurus* sp.
    - Family Anguidae
    - Family Varanidae
  - Order Ophidia
  - Order Crocodylia
    - Family Crocodylidae
      - cf. *Crocodylus*
      - cf. *Allognathosuchus*
      - cf. *Pristichampsus*

[1]Testudinata identified by J. H. Hutchison.

Class Mammalia

Order Multituberculata

Family Neoplagiaulacidae Ameghino, 1890

Ectypodus Matthew and Granger, 1921

Ectypodus sp., cf. E. childei (Kuhne, 1969)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44565 (M1L), UCM 44566 (M2U). Loc. 81008; UCM 45256 (P4L).

Discussion: Krishtalka (in Stucky and Krishtalka, 1982) has discussed these specimens in detail. Nothing can be added to his treatment.

Measurements: Given in Stucky and Krishtalka (1982).

Order Marsupicarnivora

Family Didelphidae Gray, 1821

Mimoperadectes Bown and Rose, 1979

Mimoperadectes?, n. sp.

Fig. 16

Referred specimens: Palaeosyops borealis zone.- Loc. 80061; UCM 45252 (P3L, M1Tr, M2L, M3Tr).

Description: P3L is premolariform with a posterolabial crest running down from the apex of the protoconid to the labial border of the postcingulid. There are no talonid cusps, but a talonid basin is developed posterolingual to the protoconid and anterior to the well developed postcingulid. The paraconid on M1L, M2L and M3L is nearly equal in height to the metaconid, but is anteriorly placed.

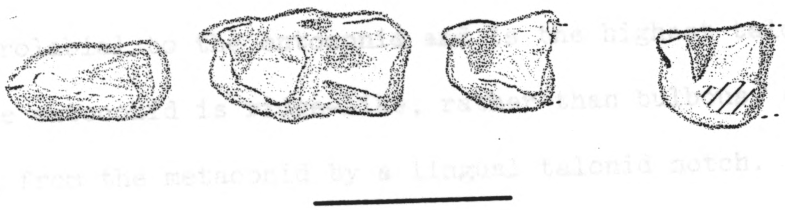

Fig. 16. Mimoperadectes?, n. sp., UCM 45252 (P3-M3L). Bar is 2 mm.

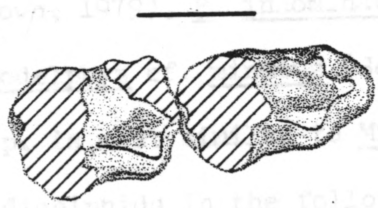

Fig. 17. Palaeictops sp., cf. P. bridgeri, UCM 46560 (M2-3L). Bar is 2 mm.

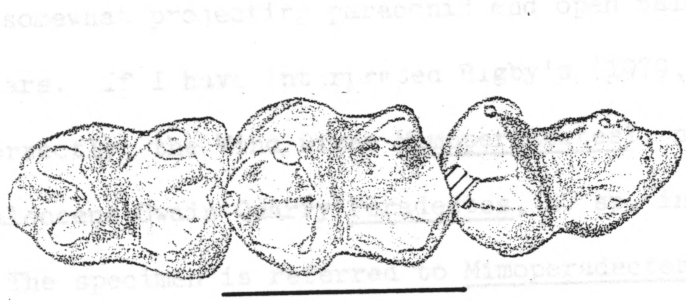

Fig. 18. Pantolestes sp., cf. P. longicaudus, UCM 45435 (M1-3L). Bar is 5 mm.

The protoconid is relatively low and not much higher than the metaconid or paraconid. On M2L the talonid is slightly narrower and shorter than the trigonid. The hypoconulid lies closely appressed and posterolabial to the entoconid and is the highest talonid cusp. The entoconid is ridge-like, rather than bulbous, and is separated from the metaconid by a lingual talonid notch.

Discussion: Wind River *Mimoperadectes*?, n. sp. is smaller than *Mimoperadectes labrus* (Bown and Rose, 1979), and *Thylacodon pusillus* (=*Peradectes pusillus*, Clemens, ms.), and larger than *Peradectes*, n. sp. (Clemens, ms.), *P. elegans* (Gazin, 1956), *P. pauli* (Gazin, 1956), *P. chesteri* (Bown, 1979), *P. innominatum* (McKenna, 1960; Bown, 1982), and *Nannodelphys* cf. *minutus* (Setoguchi, 1975). *Mimoperadectes*?, n. sp. is most similar to *Mimoperadectes labrus* among North American didelphids in the following characters: a relatively low protoconid, equal sized metaconid and paraconid, and talonid basin construction. It differs from *M. labrus* but resembles *Peradectes* in having a labial posterior protoconid ridge on P4L and a somewhat projecting paraconid and open talonid notch on the lower molars. If I have interpreted Rigby's (1979, 1980) discussion correctly, the Wind River *Mimoperadectes*?, n. sp. is most similar to Paleocene Swain Quarry *Peradectes*, n. sp. in size and morphology. The specimen is referred to *Mimoperadectes* because of the relations of the metaconid and paraconid, a feature considered derived among North American didelphids. However, *Mimoperadectes*?, n. sp. is most certainly more primitive than *M. labrus* in P4L morphology and openness of the talonid notch. The height of the hypoconulid, narrowness of the talonid basin, presence of a talonid notch, and relations of the paraconid and metaconid may be of value in future systematic revisions of North American Paleogene didelphids. While a new species, and probably a new genus of didelphid is indicated by the morphology of UCM 45252, this species is not named pending direct comparison of Peradectes-like type specimens and the potential recovery of more complete fossil material. UCM 45252 represents the first record of Peradectes-like marsupials from the Wind River Formation.

Measurements: M1L-L, 1.95; M2Tr-W, 1.20; M2Ta-W, 1.05.

Peratherium Aymard, 1850

Discussion: Crochet (1969, 1977) has indicated that North American marsupials referred to the genus Peratherium are generically distinct from European Peratherium. If this is the case, North American species presently assigned to Peratherium would be known under the name Entomacodon Marsh 1872 or Herpetotherium Cope 1873 (see Robinson, 1968a). I retain the use of the generic name Peratherium for all North American Paleogene didelphids which have the hypoconulid directly behind the entoconid and a distinct hypoconulid-entoconid notch until the relationships of European and North American Peratherium spp. are well documented.

Peratherium sp., cf. P. marsupium (Troxell, 1923)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44336 (MTa), UCM 44574 (dp3U), UCM 44580 (M3U), UCM 46719 (M4Ta).

Palaeosyops borealis zone.- Loc. 79040; UCM 42869 (M2 or 3L), UCM 45234 (M1L), UCM 45545 (M3-4U). Loc. 80061; UCM 44870 (M3U).

Discussion: Lower molars from the Red Creek localities agree in morphology and size with P. marsupium (Simpson, 1928; see Bown, 1982). As is characteristic of Peratherium, the upper molar paracone is reduced in size relative to the metacone. Stylar cusps A and E are apparently absent. Stylar cusps B and D are both developed as stylar ridges. Stylar cusp C is conjoined with stylar cusp D and well separated from B. The preprotocrista is in line and parallel to the preparacrista. The posterior margin of the protocone is at an approximate 45 degree transverse angle as in Oligocene Peratherium. The metaconule is well developed relative to the paraconule.

M4U differs from the other upper molars in the dominance of the paracone. The metacone is, however, much better developed than in Peratherium sp. A discussed below. Stylar cusp A is the only cusp on the stylar area. Behind stylar cusp A there is a stylar ridge which runs from just posterior to stylar cusp A to labial to the apex of the metacone. The M4U is quadrate and resembles the M4U of Mimoperadectes labrus (see Bown and Rose, 1979, Pl. 2, Fig. 1). The possible dp3U of P. marsupium (UCM 44574) differs from this tooth in Didelphis by having no stylar area and a bulbous metacone.

Measurements: M1L-L, 2.70; M1L-W, 1.50; M2 or 3L-L, 2.90; M2 or 3L-W, 1.65; M3U-L, 2.55-2.70; M3U-W, 2.50-2.90; M4U-L, 2.25; M4U-W, 2.80.

Peratherium sp., cf. P. comstocki Cope, 1884

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44573 (M2U), UCM 45337 (lingual fragment upper molar).

Discussion: The paracone and area of stylar cusp E are worn by occlusal attrition on the only complete upper molar of this taxon. In occlusal view the M2U is more transverse than in Peratherium sp., cf. P. marsupium. The paracone is more nearly equal in height to the metacone. Stylar cusp C is present and all stylar cusps are inflated and bulbous. The size relations of the stylar cusps are: D > B > C > A.

These specimens are assigned to P. comstocki on the basis of their large size and lithosympatric occurrence with upper molars referred to P. marsupium.

Measurements: M2L-L, 2.75; M2L-W, 3.25.

Peratherium sp. A (small)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44576 (M1L), UCM 44578 (MTa), UCM 44579 (upper molar fragment), UCM 44881 (M4U).

Palaeosyops borealis zone.- Loc. 79040; UCM 42864 (M1L), UCM 42865 (M2 or 3L), UCM 42870 (M2 or 3L), UCM 42872 (M1U). Loc. 80061; UCM 44575 (M4Ta), UCM 44577 (M4Ta), UCM 44606 (M1Tr), UCM 44866 (M2 or 3L), UCM 44867 (M4U), UCM 44868 (M2 or 3U), UCM 44869 (M1U), UCM 45255 (M4U), UCM 45285 (M2U).

Discussion: The lower molars are as in typical North American _Peratherium_ spp. with a large cuspate entoconid and the hypoconulid small and directly behind the entoconid. A notch separates the entoconid and hypoconulid. Upper molars have the metacone larger than the paracone (except on M4U). On M1U stylar cusps A, B and D are present with D developed as a stylar ridge. M2U stylar cusps are bulbous and not ridge-like. Stylar cusp B is the largest, followed by D and C, which are subequal in size. Stylar cusp A is the smallest. The presence of stylar cusp E cannot be determined because of occlusal attrition in the area of this cusp. The upper molars are truly dilambdodont with the postparacrista and premetacrista joined in a complete centrocrista. M4U has a long preparacrista which connects with stylar cusp A. Stylar cusp C is always prominent as in Oligocene _Peratherium_.

This species of marsupial is by far the most common in the Red Creek collections. This species is small for _Peratherium knighti_ (McGrew, 1959; Bown, 1982) and may represent _Peratherium morrisi_ (Gazin, 1962). Specimens from the Lost Cabin Member referred to _Peratherium_ sp., cf. _P_. _chesteri_ by Guthrie (1971) probably also represent this species (_Peratherium_ _chesteri_ Gazin, 1952 = _Peradectes_ _chesteri_; see Bown, 1979a).

Measurements: M1L-L, 1.60-1.80; M1L-W, 0.80-1.00; M2 or 3L-L, 1.70-1.90; M2 or 3L-W, 0.95-1.05; M1U-L, 1.75; M1U-W, 1.60; M2U-L, 1.70; M2U-W, 1.90; M4U-L, 1.00-1.30; M4U-W, 1.70-1.90.

Peratherium sp. B (small)

Referred specimens: Lambdotherium zone.- Loc. 81008; UCM 46614 (M2-3U).

Discussion: The ectostylar area on these teeth is more deeply excavated than in Peratherium sp. A. They are not truly dilambdodont; a notch is formed labial to the metacone on the premetacrista before it reaches the postparacrista. The postparacrista continues behind the metacone. The protocone is relatively smaller than in Peratherium sp. A. The size trends in the stylar cusps are: B > D > C > A.

The more deeply excavated ectostylar area and the non-dilambdodont condition separate this species from Peratherium sp. A. It might be argued that these two teeth represent an individual variant of Peratherium sp. A. However, I feel it necessary to preserve the variations in morphology of this specimen by referring it to another taxon.

Measurements: M3U-L, 1.65; M3U-W, 1.75.

Didelphidae, sp. indet.

Referred specimens: Palaeosyops borealis zone.- Loc. 80061; UCM 45288 (M3U).

Discussion: This tooth is smaller than in Peratherium mcgrewi Bown, 1979. The paracone is more nearly equal to the metacone in height, in contrast to Peratherium sp. A or Peratherium sp. B.

The protocone is much narrower than the stylar area. Stylar cusps B and E are well developed, with E being a continuation of the postmetacrista and the larger.

This specimen very closely resembles Nannodelphys cf. minutus from the Late Eocene of the Badwater area (Setoguchi, 1975), but differs from that genus and species in having a reduced paracone, relatively narrow protocone and long postmetacrista. In all probability this specimen is representative of an as yet unnamed early to middle Eocene marsupial.

Measurements: M3U-L, 1.15; M3U-W, 1.10.

Order Proteutheria

Family Palaeoryctidae (Winge, 1917)

Didelphodus Cope, 1882

Didelphodus sp., cf. D. altidens (Marsh, 1872)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44583 (M2U fragment), UCM 44563 (ML). Loc. 81031; UCM 46467 (P4L-M1L). Palaeosyops borealis zone.- Loc. 80061; UCM 44875 (ML), UCM 44876 (ML), UCM 44877 (ML). Loc. 81010; UCM 46591 (ML). Loc. 81027; UCM 46718 (M2U).

Discussion: These lower molars referred to Didelphodus altidens display a range of morphology which may be attributable to differing tooth positions, differences in occlusal attrition, or differences between anagenetic populations of a single species. The trigonids on some specimens are high and compressed (UCM 44876, UCM 46467), whereas on others the trigonid is low and open. The single dentary preserving the P4L-M1L is from an old individual and is heavily worn by occlusal attrition; however, the paraconid on the P4L is quite lingual and is closely appressed to the metaconid. Reference to D. altidens is based on size and morphology of the P4L (Van Valen, 1966).

Measurements: ML-L, 2.75-3.20; ML-W, 1.80-2.10.

Palaeoryctidae, sp. indet.

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 44586 (MU fragment).

Discussion: This small protocone fragment is anteroposteriorly compressed with no anterior or posterior cingulum, and is relatively high. These characters suggest that a very small palaeoryctid near the size of Oligoryctes was present at this locality.

Family Leptictidae Gill, 1872

Palaeictops Matthew, 1899

Palaeictops multicuspis (Granger, 1910)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44376 (M2L), UCM 44587 (M2L), UCM 44588 (M3L), UCM 46876 (MU fragment). Loc. 81029; UCM 46875 (M2L). Loc. 81032; UCM 46284 (partial skeleton, vertebrae, and articulated hind limb and foot elements).

Discussion: The lower molars have an anteroposteriorly compressed trigonid and medial hypoconulid. An entostylid is developed on most lower molars although obscured by occlusal attrition. The P3L-P4L agree in morphology and size with the type of _Palaeictops multicuspis_ (Granger, 1910; Novacek, 1977).

The partial skeleton (UCM 46284) and one M2L were recovered from the type locality of this species (Buck Spring, s.l., see Chapter II). Specimens from the Deadman Butte locality (Loc. 80062) differ from the former two specimens in having a more anteroposteriorly compressed trigonid.

Measurements: P4L-L, 3.90; P4L-W, 2.00; M1L-L, 2.95-3.05; M1L-W, 2.40; M2L-L, 2.80; M2L-W, 2.55; M3L-L, 3.30; M3L-W, 2.00.

Palaeictops sp., cf. _P. bridgeri_ Simpson, 1959

Fig. 17

Referred specimens: _Palaeosyops borealis_ zone.- Loc. 81010; UCM 46560 (M2-3L). Loc. 79040; UCM 42828 (M2L).

Discussion: The molar paraconids are closely appressed to the metaconid but are not nearly as appressed as in _P. multicuspis_. The hypoconulid on M2-3L forms a prominent posterior projection. The hypoconid on M3L is equal in height to the hypoconulid and is higher than the entoconid. The talonid is long and narrow. There is a small entostylid on M3L.

Although smaller, the M3L talonid agrees closely with the description of this tooth in the type of _P. bridgeri_ (AMNH 56032, Simpson, 1959). The M3L differs from the type of _P. multicuspis_ (AMNH 14791) in the projection of the hypoconulid, narrow talonid, presence of a small cusp between the hypoconulid and entoconid, and in the relative heights of the hypoconid and entoconid. This is the first record of P. bridgeri in the Wind River Formation.

Measurements: M2L-L, 3.00-3.20; M2L-W, 2.20-2.40; M3L-L, 3.20; M3L-W, 1.70.

Leptictidae, sp. indet.

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44878 (MTr), UCM 46876 (M3L).

Discussion: The single M3L referred here differs from this tooth in other Wind River Formation leptictids in the low, medial position of the paraconid, dominance of the metaconid, small size, and in the nearly equal length of the trigonid and talonid. The trigonid is relatively high and the precingulid ends medial and just below the base of the paraconid.

The dominance of the metaconid and medial position of the paraconid suggest a relationship with Prodiacodon (Novacek, 1977). The tooth is referrable to the Leptictidae on the basis of the relatively high and broad trigonid. The small size and morphology of these teeth suggests that a third species of leptictid is represented from the Wind River strata in the Red Creek-Deadman Butte area.

Measurements: M3L-L, 2.90; M3L-W, 1.90.

Family Pantolestidae Cope, 1884

Palaeosinopa Matthew, 1901

Palaeosinopa didelphoides (Cope, 1881)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 46878 (M2Tr). Loc. 81029; UCM 46917 (M2Tr), UCM 46982 (M1L), UCM 46998 (M3Tr).

Discussion: The molar trigonids on these specimens have a well developed paralophid and lingual paraconid. A notch is developed between the entoconid and hypoconulid. These specimens are only slightly larger than the type of P. didelphoides (AMNH 4804) but agree in every detail of morphology. They are clearly referrable to Palaeosinopa by the lingual position of the paraconid.

Measurements: M1L-L, 5.30; M1L-W, 3.55.

Palaeosinopa veterrima Matthew, 1918

Referred specimens: Lambdotherium zone.- Loc. 81029; UCM 46983 (M2L), UCM 46984 (M1U), UCM 46985 (M2U).

Discussion: The paraconid is lingual and apparently a paralophid was developed (the tooth is worn by occlusal attrition). A series of small cuspules are present between the entoconid and hypoconulid resulting in a ridge between these two talonid cusps. The entoconid and hypoconulid are equal in height. On both upper molars the postcingulum is small and posterior to the protocone.

The single lower molar is nearly identical to AMNH 16822, a pair of lower jaws referred to P. veterrima. The lower molars differ from P. didelphoides in a stronger ridge between the hypoconulid and entoconid. The referred upper molars differ from Pantolestes sp., cf. P. longicaudus in being more transverse and in having a less developed postcingulum. The specimen referred by Guthrie (1971) to Palaeosinopa cf. veterrima (CM 22042) is clearly too large to be referred to P. veterrima on the basis of size alone and should be referred to Pantolestidae, sp. indet. until the pantolestids are more thoroughly studied.

Measurements: M2L-L, 5.60; M2L-W, 4.05; M1U-L, 4.60; M1U-W, 6.50; M2U-L, 5.20; M2U-W, 7.00.

Pantolestes sp., cf. P. longicaudus Cope, 1872

Fig. 18

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM (RP4-M1U, RC, RM1-3L, LM1-2L, IL).

Discussion: The paraconid on M1L, M2L and M3L is medial in position and projects anteriorly. There is no paralophid as in Palaeosinopa. The hypoconulid is reduced in size and lower than either the entoconid or hypoconid. The metaconid and protoconid are nearly equal in height with the paraconid much reduced in size on M1L and M2L and nearly absent on M3L. The trigonid height increases from M1L to M3L. On M1U, the paracone is slightly labial to the metacone and the hypocone is developed posterolingual to the apex of the protocone.

This specimen is referred to Pantolestes on the basis of the reduced and medial paraconid on the lower molars. It is identical to a specimen in the Carnegie Museum collections of *Pantolestes* from the Bridger Formation (TTU 3975, now part of CM collections). This is the only known specimen of *Pantolestes* from the Wind River Formation. This specimen is tentatively referred to *P. longicaudus* on the basis of size (Matthew, 1909).

Measurements: M1-3L-L, 12.80.

Family Apatemyidae Matthew, 1909

Apatemys Marsh, 1872

Apatemys sp., cf. *A. bellulus* Marsh, 1872

Referred specimens: *Palaeosyops borealis* zone.- Loc. 79040; UCM 45551 (M2L). Loc. 80061; UCM 44874 (M2L), UCM 45291 (M2L).

Discussion: West (1973b) reviewed all Eocene and Oligocene Apatemyidae and suggested that all specimens from the early and middle Eocene were referrable to a single species, *Apatemys bellus*. Bown (1979a, 1982) has commented extensively on this systematic decision and has indicated that both size and morphological criteria can fruitfully be used to discriminate more than a single species of *Apatemys*, a position with which I agree.

The teeth here referred to *A. bellulus* are similar in size to one another and display a similarity in morphology that is distinct from the single lower molar referred to *Apatemys* sp. discussed below. The talonid on the lower molars is quadricuspate and rounded. The talonid cusps are not distinct and the anterolabial cusp and border of the trigonid are distinct. The cristid obliquid is lingual, striking the posterior trigonid below the protoconid.

The teeth agree in size with specimens from the Aycross Formation referred by Bown (1982) to A. bellulus and are here referred to that species on the basis of size.

Measurements: M1L-L (N=2), 1.85-1.90; M1L-W (N=2), 1.15-1.30; M2L-L, 1.95; M2L-W, 1.15.

Apatemys, sp. A

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44370 (M3U), UCM 44582 (M2L).

Discussion: A second, undetermined species of Apatemys is represented in the Red Creek-Deadman Butte sample. The M2L is distinctly smaller and differs in morphology from the M2L referred to A. bellulus in the following characters: the cristid obliquid strikes the posterior wall of the trigonid medially, all three talonid cusps are distinct, and the anterolabial cusp of the trigonid is distinct. The differences between this smaller Apatemys sp. A and the larger Apatemys sp., cf. A. bellulus are characters which Bown (1979a) has suggested may be of use in understanding the phylogenetic patterns of early and middle Eocene Apatemyidae.

Measurements: M2L-L, 1.40; M2L-W, 0.95.

Proteutheria, sp. indet.

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 46664 (dentary with alveoli for M3L).

Discussion: This minute dentary fragment preserves the alveoli for M3L. The anterior alveolus is oval in shape and the posterior alveolus is anteroposteriorly elongate as in most mammals. The ramus ascends at a 45 degree angle and has a well developed masseter pocket. There is no anteroposteriorly running ridge or boss at the gum line as in Nyctitherium (Robinson, 1968) or Oligoryctes (Robinson, oral communication, 1982). The small size is suggestive of an insectivore, perhaps a palaeoryctid, but identification is precluded by the lack of any dentition.

Measurements: Depth of dentary below anterior alveolus of M3L, 1.00. Estimated length of M3L, 0.70.

Order Insectivora

Family Adapisoricidae Schlosser, 1887

Scenopagus McKenna and Simpson, 1959

Scenopagus edenensis (McGrew, 1959)

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM 42827 (M1L), UCM 45501 (M1L), UCM 45542 (M2U). Loc. 80061; UCM 44882 (M2L).

Discussion: These specimens agree in size and morphology with the type and referred specimens of S. edenensis (Krishtalka, 1976a).

Measurements: M1L-L, 2.25-2.30; M1L-W, 1.60-1.70; M2U-L, 1.80; M2U-W, 2.30.

Scenopagus sp., cf. *S. edenensis* (McGrew, 1959)

Referred specimens: *Lambdotherium* zone.- Loc. 80062; UCM 44593 (M1U), UCM 44594 (MU fragment), UMC 46818 (M3L), UCM 46819 (M2L).

Discussion: These specimens agree closely with specimens identified as *S. edenensis* but differ in the upper molars in being slightly larger and in the lower molars in being slightly smaller and in having the talonid basin on M2L wider than the trigonid.

Measurements: M2L-L, 1.90; M2L-W, 1.60; M3L-L, 2.00; M3L-W, 1.40; M1U-L, 1.90; M1U-W, 2.70.

Scenopagus priscus (Marsh, 1872)

Fig. 19

Referred specimens: *Palaeosyops borealis* zone.- Loc. 80061; UCM 44880 (M2U), UCM 44885 (M2L). Loc. 81010; UCM 46548 (M2-3L).

Discussion: Lower dentitions referred to *S. priscus* are similar in morphology and size to the type of *S. priscus* (YPM 11858). The M2U referred here is similar in morphological construction to this tooth figured for *S. curtidens* (Bown, 1982), but agrees more closely in size with *S. priscus* (Krishtalka, 1976a).

Measurements: M2L-L, 1.65-1.80; M2L-W, 1.25-1.50; M3L-L, 1.90; M3L-W, 1.30; M2U-L, 1.40; M2U-W, 2.30.

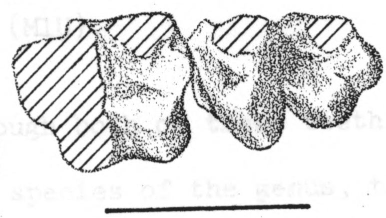

Fig. 19. Scenopagus priscus, UCM 46548 (M2-3L). Bar is 2 mm.

Fig. 20. Adapisoricidae, probably new, UCM 45279 (P4-M2L). Bar is 1 mm.

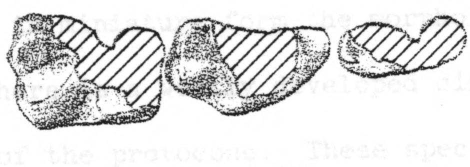

Fig. 21. Cf. Plagioctenodon, UCM 46481 (P3-M1L). Bar is 1 mm.

cf. Scenopagus sp.

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44597 (MLTr), UCM 46821 (MlU).

Discussion: Although both of these teeth are smaller than S. priscus, the smallest species of the genus, their morphology resembles closely published descriptions of Scenopagus (Krishtalka, 1976a; Bown, 1982). The paraconid on the lower molar trigonid fragment is ridge-like, and closely appressed to the metaconid. The metaconid is higher than the protoconid, but subequal in overall size. The trigonid is approximately 30 percent smaller than the trigonid of M2L preserved in the type of S. priscus. The MlU is smaller in the transverse dimension than in published measurements of S. priscus (Krishtalka, 1976a). The tooth, however, agrees in morphology with the figures of S. curtidens (Bown, 1982). The paracone and metacone are tall and rounded; there is no preparacrista. The postmetacrista descends onto the metastylar area. Both conules are well developed. The protocone is as tall as the paracone and metacone. The hypocone lies posterolingual to the apex of the protocone but is labial to the lingual side of the protocone. The hypocone is cuspate and mirrors in miniature form the morphology of the paracone and metacone. There is a weakly developed cingular area just anterior to the apex of the protocone. These specimens could represent either a new species of Adapisoricid closely related to S. priscus or simply be representative of a population ancestral to larger Bridgerian S. priscus.

Measurements: M1U-L, 1.46; M1U-W, 1.71.

Macrocranion Weitzel, 1949

Macrocranion nitens (Matthew, 1919)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44591 (MU fragment). Loc. 81008; UCM 46615 (M1U).

Discussion: These teeth are similar to described material of M. nitens (Krishtalka, 1976a). The teeth are more bunodont than in Scenopagus, but resemble teeth of this genus in their overall morphology. The paracone and metacone are low and diverge ventrally. The teeth are less transverse than in Scenopagus, and thus they are narrower across their medial portion. The preparacrista and postmetacrista are weakly developed. There is a very weak ridge that connects the hypocone to the posterior wall of the protocone, a character diagnostic of M. nitens (Krishtalka, 1976a).

Measurements: M1U-L, 1.72; M1U-W, 2.23.

Adapisoricidae, probably new

Fig. 20

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 46827 (MLTr).

Palaeosyops borealis zone.- Loc. 80061; UCM 44884 (M2L), UCM 45279 (P4L-M2L, M1LTr only).

Description: Size is 25 percent larger than in Talpavus nitidus, near the size of S. edenensis. P4L is semimolariform. The paraconid projects from the base of the protoconid and is less tall than the metaconid. The talonid basin is very narrow and rimmed. Four minuscule cusps occur on the talonid; three on the posterior rim. One occurs at the convergence of the cristid obliquid and the hypolophid (hypoconid?), one medial on the hypolophid (hypoconulid?), and one at the posterolingual corner of the talonid rim (entoconid?). The fourth cusp is anterior to the posterolingual cusp. The cristid obliquid is labially concave.

On the M1L trigonid the paraconid is lower than the metaconid and protoconid and is ridge-like with the crest of this ridge parallel to the posterior edge of the trigonid. The paraconid is anteriorly concave. The metaconid is subequal in height to the protoconid but more anteroposteriorly compressed.

M2L is similar to this tooth in the type specimen of _Talpavus nitidus_ (YPM 13511) differing only in a less developed notch between the hypoconulid and entoconid, and in the paraconid ridge being more anteriorly concave. As in the type of _T. nitidus_ there is no paraconid; rather a strong ridge is developed which is anteriorly concave. The metaconid is the taller and larger cusp of the trigonid. The entoconid is the highest talonid cusp, followed by the hypoconid which is nearly equal in height to the entoconid. The hypoconulid is medial and small and projects posteriorly. In posterior view all three talonid cusps slope lingually. The cristid obliquid slopes down to just above the base of the trigonid and does not rise up to a level equal to its beginning on the hypoconulid. The M2L talonid is narrower than the trigonid.

Discussion: These specimens probably represent a new genus and species of adapisoricid closely related to Talpavus nitidus and possibly Centetodon. They differ, however, from the former in their larger size, a more anteriorly concave paraconid on M1L and M2L, and a semimolariform P4L with a well developed talonid basin. The P4L is similar to P4L in Centetodon in talonid construction, but has a much taller paraconid and lacks the deep labial flexure between the anterior and posterior roots.

Measurements: P4L-L, 1.42; P4L-W, 0.85; M1L-WTr, 1.22; M2L-L (N=2), 1.60; M2L-W, 1.21-1.33.

Family Geolabididae McKenna, 1960

Centetodon Marsh, 1872

Centetodon bembicophagus Lillegraven, McKenna and Krishtalka, 1981

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44585 (M2U).

Palaeosyops borealis zone.- Loc. 80061; UCM 44883 (M2L), UCM 44886 (P4L), UCM 45268 (M3L).

Discussion: These teeth agree in morphology and size with descriptions of Centetodon bembicophagus (as Centetodon sp. B in Krishtalka and West, 1979; Lillegraven et al., 1981). The cristid obliquid on the lower molars is labially concave and connects to the talonid directly below the protoconid-metaconid notch. On the upper molar the conules are relatively weak and the lingual root is not bifurcate. The pre- and postcingula on the upper molar are also weak.

The upper molar from Deadman Butte locality (Loc. 80062) is the earliest record of this species and indicates that two species were present during the Lostcabinian; _C. pulcher_ is known from the Huerfano basin (Krishtalka and West, 1979; Locality VI, Robinson, oral communication, 1982).

Measurements: P4L-L, 1.38; P4L-W, 0.70; M2L-L, 1.54; M2L-W, 0.91; M3L-L, 1.36; M3L-W, 0.86; M2U-L, 1.09; M2U-W, 1.53.

Centetodon, sp. indet.

Referred specimens: _Lambdotherium_ zone.- Loc. 80062; UCM 44602 (MLTr), UCM 44605 (MLTr), UCM 44607 (MLTr), UCM 44609 (MLTr), UCM 44611 (MU protocone), UCM 46824 (MLTa), UCM 46826 (MU protocone). _Palaeosyops borealis_ zone.- Loc. 80061; UCM 44852 (MU protocone), UCM 44873 (MU protocone).

Discussion: These fragmentary specimens are most certainly referrable to _Centetodon_, but are not assignable to any species because of their fragmentary nature. Two of these specimens are, however, worthy of additional comment. UCM 44607, a molar trigonid fragment, is larger than any other trigonid in the sample. It also differs in having an anteriorly projecting paraconid that is labially concave and in having a strong anterior cingulum. UCM 46826 is a protocone fragment which has especially strong conules that are more developed than on the upper molar referred to _C. bembicophagus_. These two fragmentary specimens are different in morphology from _C. bembicophagus_ and may indicate a different species of _Centetodon_ in the sample from the Deadman Butte locality (Loc. 80062). The differences in morphology are suggestive of C. pulcher Marsh (1872; Lillegraven et al., 1982), or a greater amount of variation in latest Wasatchian Centetodon bembicophagus than occurs in other insectivores from the Red Creek-Deadman Butte area.

Family Nyctitheriidae Simpson, 1928

Nyctitherium Marsh, 1872

Nyctitherium sp., cf. N. serotinum (Marsh, 1872)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44385 (MU protocone), UCM 46715 (MLTa).

Palaeosyops borealis zone.- Loc. 80061; UCM 44879 (MU fragment), UCM 44881 (MU fragment), UCM 44887 (ML), UCM 45275 (MU fragment).

Discussion: The fragmentary lower molars of Nyctitherium are identified on the basis of the following criteria: 1) close approximation of the hypoconulid and entoconid; 2: a cuspate paraconid; 3) presence of a strong postmetacristid; and 4) a cristid obliquid which ascends up the posterior wall of the trigonid. Upper molars are identified on the basis of either a strong preparacrista and lack of complete dilambdodonty (Robinson, 1968) and/or a cingular bulbous salient hypocone. The lower molars are similar in size to the type of N. serotinum and lack a labial cingulum (see Krishtalka, 1976b).

Plagioctenodon Bown, 1979a

cf. Plagioctenodon Bown, 1979a

Fig. 21

Referred specimen: Lambdotherium zone.- Loc. 81031; UCM 46481 (P3-M1L, trigonids broken).

Discussion: This specimen fits the size and description of material identified as "cf. Plagioctenodon krausae" by Bown (1979a), who originally described this genus and species in the same paper. The P4L of UCM 46481 is long with a deep ectoflexid and an anteriorly projecting paraconid. The labioventral lobe of the talonid is lower than the lobe of the trigonid as in Nyctitherium (Robinson, oral communication, 1982). However, the talonid of M1L is more cuspate and the hypoconulid is more labially removed from the entoconid than in Nyctitherium. There is no diastema between P3L and P4L, and P4L and M1L. The size is smaller than in N. serotinum and closely agrees with cf. P. krausae (Bown, 1979a). This specimen differs from cf. P. krausae in the length relationships of M1L and P4L and hypoconulid morphology of M1L.

Measurements: P4L-L, 1.35; M1L-L, 1.28.

Order Chiroptera

Family Icaronycteridae Jepson, 1966

Icaronycteris Jepsen, 1966

Icaronycteris?, n. sp.

Fig. 22

Referred specimen: Palaeosyops borealis zone.- Loc. 79040; UCM 45109 (M2U).

Description: This tooth is fully dilambdodont with a large stylar area, subequal metacone and paracone and anteriorly projecting protocone with a salient hypoconal area. There is no mesostyle and both the paracone and metacone are labially concave. The ectostylar rim is deeply excavated and forms an asymmetrical parabolic concavity with its steepest edge anterior. The parastylar area is large; there apparently is no parastyle. The preparacrista swings anteriorly to the medial portion of the parastylar lobe. The postmetacrista extends to the edge of the most posterior portion of the large metastylar lobe. The apex of the paracone is more lingual and not as high as the apex of the metacone. There is no metaconule and the paraconule appears to be absent. The preprotocrista forms a ridge which swings ventrolabially as an anterior cingulum and eventually connects with the parastylar lobe and preparacrista. The postprotocrista is arcuate and runs to the base of the metacone. The apex of the protocone projects anteriorly. There is no hypocone; however, the posterior slope is expanded into a salient hypoconal shelf. In plan view the lingual base of the protocone is

Fig. 22. Icaronycteris?, n. sp., UCM 45109 (M1U). Bar is 1 mm.

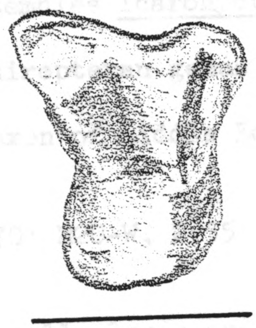

Fig. 23. Ageina tobeini, UCM 46616 (M2U). Bar is 1 mm.

Fig. 24. Alveojunctus sp., UCM 44681 (M1L). Bar is 1 mm.

squared off. There is a small cingulum which surrounds the lingual side of the tooth. In overall appearance the tooth is transverse.

Discussion: This tooth differs from all other known Eocene bats by being more transverse and by having a more elevated paracone and metacone, a more developed hypoconal lobe and a reduced lingual cingulum. The tooth differs from *I. index* and *I.? menui* in the above characters. It is also larger in size and lacks a prominent hypocone. It differs from *Archaeonycteris* in a less bulbous and anteriorly projecting protocone, and from *Ageina tobieni* in a narrower paracone and metacone and more transverse appearance. In overall appearance it resembles *Icaronycteris* more than any other early or middle Eocene chiropteran genus. In all probability, this tooth represents a new taxon of middle Eocene chiropteran.

Measurements: M2U-L, 1.70; M2U-W, 2.55.

Ageina Russell, Louis and Savage, 1973

Ageina tobeini Russell, Louis and Savage, 1973

Fig. 23

Referred specimen: *Lambdotherium* zone.- Loc. 81008; UCM 46616 (M1U).

Discussion: This tooth is identical in morphology and only slightly smaller than teeth referred to *Ageina tobeini* from the early Eocene of France (Russell et al., 1973). It differs from *Icaronycteris?*, n. sp. in being less transverse, lacking a lingual cingulum completely surrounding the protocone, more anteroposteriorly elongate paracone and metacone, less developed hypoconal area (but more developed hypoconal lobe cingulum), and less elevated paracone and metacone. These characters are all diagnostic of Ageina tobeini.

Measurements: M1U-L, 1.65; M1U-W, 2.00.

Order Primates

Family Microsyopidae Osborn, 1892

Microsyops Leidy, 1872

Microsyops sp., cf. M. scottianus Cope, 1881

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44331 (P4L), UCM 44334 (MU), UCM 44342 (P4L), UCM 44364 (M1L), UCM 44398 (MU), UCM 44404 (M2L), UCM 44408 (MU), UCM 44418 (MU), UCM 44609 (MU), UCM 44664 (M3L), UCM 44666 (M3L), UCM 44667 (MU), UCM 44668 (MU), UCM 44697 (M2L), UCM 44698 (M1L), UCM 45341 (MU), UCM 46444 (M2L), UCM 46449 (MU), UCM 46450 (P4L), UCM 46451 (P4L). Loc. 80063; UCM 44299 (M1-3U), UCM 44300 (ML), UCM 44301 (MU), UCM 44302 (ML). Loc. 80083; UCM 46522 (P4L). Loc. 81008; UCM 46618 (M3L), UCM 46619 (M3U), UCM 46620 (P4U). Loc. 81029; UCM 46947 (MU), UCM 46950 (M3U), UCM 46951 (M3L). Loc. 81033; UCM 46406 (P4L). Loc. 81034; UCM 46407 (M1L).

Palaeosyops borealis zone.- Loc. 79040; UCM 42810 (P4L), UCM 42811 (MTa), UCM 42812 (MU), UCM 42813 (dp4U), UCM 42814 (2MTr), UCM 42816 (MTr), UCM 42817 (MU), UCM 45236 (M1L), UCM 45237 (P4L), UCM 45238 (M3L), UCM 45239 (M2L), UCM 45241 (M1L), UCM 45367 (M3U), UCM 45368 (P4U). Loc. 79041; UCM 44904 (M2-3L, fragment). Loc. 79043; UCM 42202 (P4, M2-3L), UCM 46759 (I-M3L, fragment), UCM 45522 (M3L).

Loc. 80061; UCM 44853 (M3L), UCM 44856 (M2L), UCM 44857 (M1L), UCM 44859 (M3L), UCM 44860 (M3U), UCM 44862 (M3U), UCM 45261 (M1L), UCM 45263 (M3Ta). Loc. 80065; UCM 45310 (MU). Loc. 81010; UCM 46545 (P4-M1L), UCM 46581 (P4Ta), UCM 46593 (M2L), UCM 46594 (P4U). Loc. 81047; UCM 46427 (P4-M3L).

Discussion: Szalay (1969) has recently reviewed most North American *Microsyops* materials and suggested that *M. scottianus* and *M. elegans* may prove to be synonomous. The sample of primarily isolated teeth and some fragmentary dentary remains from the Red Creek-Deadman Butte area exhibits a wide range of morphological variation. P4L varies in morphology from being molariform to submolariform. The talonid is either simple with a posterior ridge, or with three well developed talonid cusps. The structure of the lower molar paraconid is also variable, ranging in morphology from an anterior cusp to a paralophid ridge. The hypoconulid on the lower molars may be central or closely approximated to the entoconid. On the upper molars, the hypocone is variable in its development. None of the above characters appear to be correlated with size or stratigraphic range. Large samples of *Microsyops* from single stratigraphic horizons in the Wind River Formation are currently under study by J. D. Swarts (CM). His analysis should help resolve the paradox of variation within *Microsyops* from the Wind River Formation. Reference to *Microsyops* sp., cf. *Microsyops scottianus* is based on Szalay's (1969) suggestion that all *Microsyops* from the upper part of the Wind River Formation in this size range are referrable to that

Table 5. Tooth measurements of Microsyops sp., cf. M. scottianus from the Lambdotherium and Palaeosyops borealis zones of the Wind River Formation (UCM collections only).

	Lambdotherium zone				Palaeosyops borealis zone			
Measurement	N	Range	$\overline{X}$	SD	N	Range	$\overline{X}$	SD
P4L-L	6	3.50-3.95	3.73	0.18	6	3.30-3.85	3.61	0.19
P4L-W	6	2.35-2.90	2.66	0.20	6	2.20-2.65	2.48	0.20
M1L-L	2	3.60	3.60	-	6	3.80-4.20	3.98	0.15
M1L-W	2	2.75	2.75	-	6	2.65-3.10	2.85	0.16
M2L-L	3	4.20-4.40	4.37	0.15	7	3.70-4.50	4.11	0.25
M2L-W	3	3.00-3.60	3.27	0.31	7	2.70-3.40	3.11	0.24
M3L-L	4	4.40-4.75	4.60	0.15	8	3.90-4.80	4.48	0.33
M3L-W	4	2.70-2.90	2.81	0.09	8	2.55-3.10	2.84	0.17
dp4U-L	-	-	-	-	1	3.30	-	-
dp4U-W	-	-			1	3.80	-	-
P4U-L	1	3.70	-	-	2	3.00-3.80	3.40	-
P4U-W	1	4.20	-	-	2	3.30-4.50	3.90	-
MU-L	8	3.75-4.40	4.03	0.25	4	3.90-4.50	4.20	0.29
MU-W	8	4.30-5.20	4.68	0.32	4	4.50-5.10	4.88	0.29
M3U-L	3	3.10-4.00	3.73	0.55	1	3.60	-	-
M3U-W	3	4.00-4.50	4.20	0.26	1	4.10	-	-

species. The type of Microsyops scottianus was recovered from the Wind River Basin (Cope, 1881).

Measurements: Listed in Table 5.

Microsyops lundelius (White, 1962)

Referred specimens: Palaeosyops borealis zone.- Loc. 79041; UCM 45389 (MU protocone fragment), UCM 46499 (IL). Loc. 81010; UCM 46546 (MU, gutted). Loc. 81023; UCM 46758 (M2-3L).

Discussion: UCM 45389 and 46758 are positively referred here; the other specimens are only tentatively referred. Microsyops lundeliusi is easily identified by its large size and low crowned and more bunodont dentition. The lower incisor is referred here on the basis of its similar root structure and crown outline to UCM 23497, a specimen of M. lundeliusi from the upper Huerfano beds. The P4L discussed below as Microsyops sp. may, upon the recovery of additional material, represent a Lambdotherium zone representative of a smaller M. lundeliusi population.

Measurements: M2L-L, 5.70; M2L-W, 4.20; M3L-L, 6.40; M3L-W, 3.90.

Microsyops sp.

Referred specimen: Loc. 81029; UCM 46948 (P4L).

Discussion: This single isolated P4L is outside of the size range of referred Microsyops scottianus (Szalay, 1969) and Microsyops sp., cf. M. scottianus reported above. It could represent a P4L from an individual of Lambdotherium zone M. lundeliusi, but is smaller than any P4L of that species (Robinson, 1966; Szalay, 1969). All three talonid cusps are well defined, but the talonid is narrow. The paraconid is low and not as cuspate as occurs in most P4L of M. lundeliusi. The specimen is nearly the same size as Microsyops sp. from Carter Mountain and intermediate in size between M. scottianus/elegans and M. annectens (Szalay, 1969).

Measurements: P4L-L, 4.40; P4L-W, 2.90.

Uintasorex Matthew, 1909

Uintasorex sp., cf. U. parvulus Matthew, 1909

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44367 (MU), UCM 44612 (M2U), UCM 44613 (M1U), UCM 44614 (MU), UCM 44615 (MU), UCM 44616 (MU), UCM 44617 (MU), UCM 44618 (MU fragment), UCM 44662 (M2L), UCM 44663 (M2L), UCM 44676 (M3U), UCM 44683 (MU), UCM 44689 (MU fragment), UCM 44694 (M2L), UCM 45356 (M3U), UCM 45359 (M2Tr), UCM 46452 (MU), UCM 46453 (IL), UCM 46455 (M1L), UCM 46757 (MU fragment). Loc. 81008; UCM 43736 (IL).
Palaeosyops borealis zone.- Loc. 80061; UCM 44863 (M2U), UCM 44864 (M3U), UCM 44865 (M2L), UCM 45260 (MU fragment).

Discussion: Specimens here referred to Uintasorex sp., cf. U. parvulus agree more closely with the morphological characteristics of Uintasorex than Niptomomys as discussed by Szalay (1969b), and are similar in morphology to teeth referred to U. parvulus by Bown (1982), but are distinctly larger. The talonid of the lower molars is much wider than the trigonid on the lower molars. The M1L paraconid is formed into a ridge (paralophid) which is parallel to the ridge formed by the metaconid and protoconid. The paraconid is absent on M2L. The upper molar conules are nearly medial in position and the postcingulum is suggestive of a hypoconal cingulum on some upper molars. In the above characters they are closer to <u>Uintasorex</u> than <u>Niptomomys</u>. The specimens here referred to <u>Uintasorex</u> are, however, larger than any other teeth reported for <u>Uintasorex</u>.

<u>Measurements</u>: M1L-L, 1.30; M1L-W, 1.05; M2L-L (N=3), 1.15; M2L-W, 0.90-1.10; M1U-L, 1.10;M1U-W, 1.40; M2U-L (N=2), 1.10-1.15; M2U-W, 1.35-1.40; M3U-L, 1.00; M3U-W, 1.10-1.15.

<u>Alveojunctus</u> Bown, 1982

<u>Alveojunctus</u> sp.

Fig. 24

<u>Referred specimen</u>: <u>Lambdotherium</u> zone.- Loc. 80062; UCM 44681 (M1L).

<u>Discussion</u>: This specimen represents the earliest known occurrence of this rare and newly described uintasoricine primate (Bown, 1982). The most diagnostic features of <u>Alveojunctus</u> are the confluence of the trigonid and talonid basins, the bunodonty of the lower molars, and the enlarged entoconid. This specimen compares favorably with the type of <u>A</u>. <u>minutus</u> (USGS 2005) but differs in having a much higher trigonid and more developed cusps.

<u>Measurements</u>: M1L-L, 1.60; M1L-W, 1.10.

Family Paromomyidae Simpson, 1940

Ignacius Matthew and Granger, 1921

cf. Ignacius sp.

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44354 (M1U), UCM 44358 (M3L), UCM 44389 (P4U), UCM 44672 (M1U), UCM 44680 (M1L), UCM 45335 (M3U), UCM 46601 (M2L), UCM 46756 (M3Ta).

Discussion: Bown and Rose (1976) and Rose (1981) have outlined the differences in the upper and lower dentitions of Ignacius and Phenacolemur. The specimens identified as Ignacius sp. conform very closely to their descriptions. The upper molars have a V-shaped centrocrista with the postparacrista much longer than the premetacrista. The M3U has a well developed hypoconal lobe which is as developed as in P. praecox (Simpson, 1955, Pl. 33, Fig. 3), but not nearly as developed as in P. jepseni (Simpson, 1955, Pl. 33, Fig. 4) or UCM 46511, an M3U referred to Phenacolemur sp. discussed below. The paraconid is closely approximated to the metaconid on M1L and is absent on M2L, where a strong paracristid connects with the metaconid. A character which distinguishes Ignacius from Phenacolemur in this sample is the well developed cristid obliquid in these specimens referred to Ignacius which ascends up the posterior wall of the trigonid. The cristid obliquid morphology is apparently also present in Elwynella (see Rose and Bown, 1982). There is a deep talonid notch and the hypoconulid is small but easily distinguished.

These specimens do not readily fit into a named species of Ignacius and may represent the newly described genus Elwynella, specimens of which I have not seen (Rose and Bown, 1982). The specimens are larger than in I. mcgrewi (Robinson, 1968b). Molar width is, relatively, less than in I. graybulliensis (Bown and Rose, 1976; Bown, 1979a), and the molars are similar in proportions to I. frugivorus.

Measurements: M1L-L, 2.10; M1L-W, 1.60; M2L-L, 2.05; M2L-W, 1.55; M3L-L, 2.70; M3L-W, 1.60; P4U-L, 1.90; P4U-W, 2.15; M1U-L, 2.05; M1U-W, 2.40; M3U-L, 2.10; M3U-W, 2.10.

Phenacolemur Matthew, 1915

Phenacolemur sp.

Referred specimens: Lambdotherium zone.- Loc. 79045; UCM 45377 (M1L).

Palaeosyops borealis zone.- Loc. 81010; UCM 46547 (M1L-2L). Loc. 81022; UCM 46511 (M3U).

Discussion: These specimens conform closely to materials of Phenacolemur. The lower molars are bunodont and contrast sharply in morphology with material referred above to Ignacius sp. The talonid basin of the M2L is shallow. The preentocristid and postmetacristid meet to form a strong lingual wall; there is no talonid notch. The cristid obliquid is labial and does not rise up the posterior wall of the trigonid. There is no paraconid on M2L but a strong paracristid connects with the metaconid. M3U is very much as in P. jepseni in having a large hypoconal lobe. These teeth indicate a close relationship of Phenacolemur sp. in this sample to P. jepseni but are too large to be referrable to that species.

Measurements: M1L-L, 2.90-3.15; M1L-W, 2.30-2.40; M2L-L, 2.60; M2L-W, 2.40; M3U-L, 3.00; M3U-W, 3.10.

Family Omomyidae (Trouessart, 1879)

Anemorhysis Gazin, 1958

cf. Anemorhysis sp.

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 45350 (P4L).

Discussion: This P4L is smaller than any other omomyid P4L in the sample from the Red Creek-Deadman Butte area. It closely resembles the type of Anemorhysis sublettensis (USNM 19205) in its small size and comparatively large talonid basin. This specimen differs from A. sublettensis, however, in a more lingually open trigonid. Based on illustrations of specimens assigned to Anemorhysis (Szalay, 1976), this difference in trigonid structure is within the P4L morphologic variation of Anemorhysis.

Measurements: P4L-L, 1.50; P4L-W, 1.10.

Absarokius Matthew, 1915

Absarokius sp., cf. A noctivagus Matthew, 1915

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44351 (M2L), UCM 44682 (M2L), UCM 46438 (CL).

Discussion: The CL is nearly identical to that tooth in the type of A. noctivagus nocerai (AMNH 55215, Robinson, 1966). This tooth would appear to be too large to be referred to Aycrossia lovei (see below; Bown, 1979b). The M2L's referred here differ from the specimen of A. lovei in having less crenulate enamel and a pre-entocristid which extends to the base of the metaconid, resulting in a more closed off talonid notch.

Measurements: CL-L, 1.00; CL-W, 1.50; M2L-L (N=2), 2.40-2.50; M2L-W (N=2), 1.90-2.00.

Absarokius witteri Morris, 1954

Referred specimens: Lambdotherium zone.- Loc. 80083; UCM 45070 (M2L).

Palaeosyops borealis zone.- Loc. 80065-11; UCM (P3-M1L, trigonids of P4L and M1L broken).

Discussion: These specimens represent the second record of this rare species of Absarokius. The dentary specimen has a very small P3L in relation to P4L. P4L has a more developed exodaenodont lobe than either A. abotti or A. noctivagus. The molar enamel is also more crenulate on M1L than in either of the other two species of Absarokius. The M2L is nearly identical to the type and suggests additional criteria by which A. witteri can be separated from A. noctivagus and A. abotti. These criteria include: 1) more crenulate enamel; 2) more lingually placed cristid obliquid; 3) a lingually closed talonid basin (the postmetacristid and preentocristid form a ridge which lingually rims the talonid basin); and 4) stronger trigonid cristids connecting the protoconid with the metaconid and paraconid.

The specimen from the West Red Creek locality (UCM Loc. 80083) extends the range of this species into the late middle or early late Wasatchian (see Chapter III).

Aycrossia Bown, 1979b

Aycrossia lovei Bown, 1979b

Figs. 25, 26

Referred specimen: Palaeosyops borealis zone.- Loc. 79040; UCM 42809 (dentary with all alveoli and P3-M3L).

Discussion: This specimen is intermediate in several characters between Absarokius noctivagus and Aycrossia lovei, but shares derived characters with the latter species. This specimen is intermediate in P4L size, development of the paracristid on M1L (a small paracristid is present in the type of A. noctivagus, AMNH 15601), and bilobate labioventral border of M1L. The following characters of UCM 42809 are shared with A. lovei: 1) P2L is present (the alveolus is preserved); 2) P4L is smaller in size with a larger metaconid; 3) bilobate and straight labioventral border on M1L and M2L, respectively; 4) more developed paracristid on M1L; and 5) more crenulate enamel.

Bown (1979b) has sufficiently documented the distinctiveness of Aycrossia lovei from other Bridgerian omomyids, including Anaptomorphus. Gingerich (1981a) has presented a differing opinion.

Measurements: P3L-L, 1.20; P3L-W, 1.60; P4L-L, 2.10; P4L-W, 2.20; M1L-L, 2.30; M1L-W, 2.10; M2L-L, 2.30; M2L-W, 2.20; M3L-L, 2.60; M3L-W, 1.90.

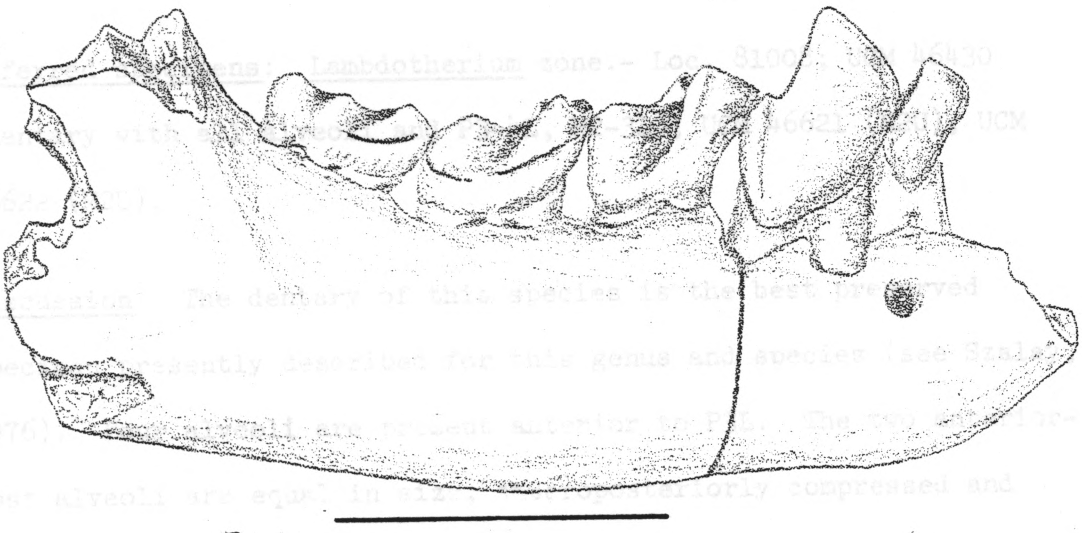

Fig. 25. Aycrossia lovei, UCM 42809 (P3-M3L), labial view. Bar is 5 mm.

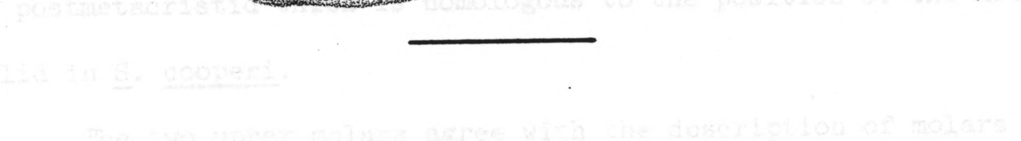

Fig. 26. Aycrossia lovei, UCM 42809 (P3-M3L), occlusal view. Bar is 5 mm.

Loveina Simpson, 1940

Loveina zephryi Simpson, 1940

Fig. 27

Referred specimens: Lambdotherium zone.- Loc. 81008; UCM 46430 (dentary with all alveoli and P3-4L, M2-3L), UCM 46621 (M2U), UCM 46622 (M2U).

Discussion: The dentary of this species is the best preserved specimen presently described for this genus and species (see Szalay, 1976). Four alveoli are present anterior to P3L. The two anteriormost alveoli are equal in size, anteroposteriorly compressed and larger than the third alveoli from the front. This third alveolus is more rounded in cross section than in other teeth anterior to P3L. The alveolus for P2L indicates this tooth is one-rooted, larger in root size than the two anterior teeth but smaller in cross sectional root area than the tooth just anterior to it. P3L and P4L are nearly identical to the type of L. zephryi (AMNH 32517); the only major difference is the openness of the trigonid on P4L (this could also be interpreted as smaller size of the metaconid and paraconid). M2-3L resemble quite closely these teeth in Shoshonius but do not have a prominent metastylid. M3L has a slight flexure on the postmetacristid which is homologous to the position of the metastylid in S. cooperi.

The two upper molars agree with the description of molars referred to L. zephryi (Szalay, 1976). Major differences from S. cooperi include larger size, absence of a mesostyle and broad lingual slope of the protocone.

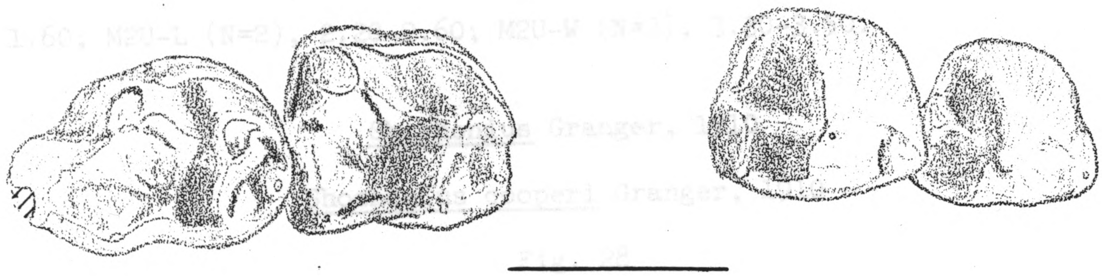

Fig. 27. Loveina zephryi, UCM 46430 (P3-4, M2-3L). Bar is 2 mm.

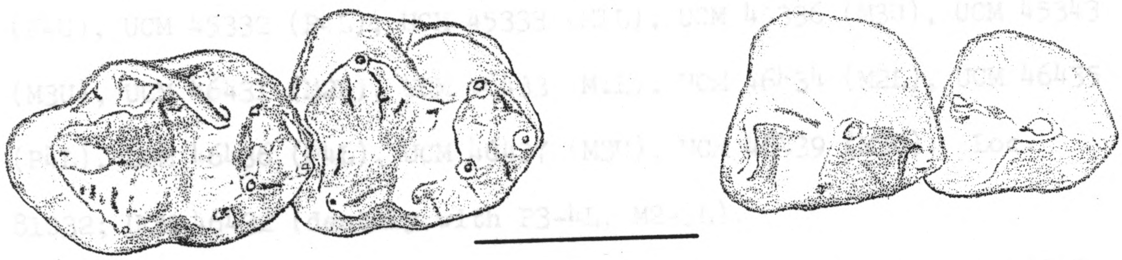

Fig. 28. Shoshonius cooperi, UCM 46432 (P2-3,M2-3L). Bar is 2 mm.

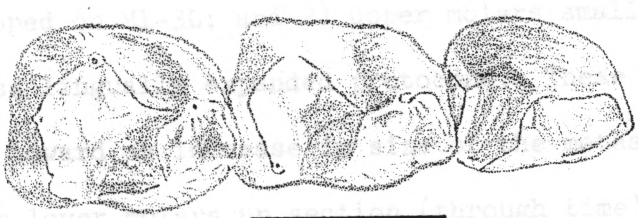

Fig. 29. Cf. Washakius, UCM 46429 (P4-M2L). Bar is 2 mm.

Measurements: P3-M3L-L, 10.20; P3L-L, 1.70; P3L-W, 1.50; P4L-L, 1.90; P4L-W, 1.70; M2L-L, 2.00; M2L-W, 1.80; M3L-L, 2.80; M3L-W, 1.60; M2U-L (N=2), 2.20-2.60; M2U-W (N=2), 3.30-3.50.

Shoshonius Granger, 1910

Shoshonius cooperi Granger, 1910

Fig. 28

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44357 (M3L), UCM 44386 (M1-2L), UCM 44400 (M2U), UCM 44405 (P4L), UCM 44678 (MU fragment), UCM 44679 (P4L), UCM 44685 (MU fragment), UCM 46687 (P4L), UCM 44688 (MU fragment), UCM 44691 (M3Ta), UCM 44699 (P4U), UCM 45332 (P4L), UCM 45333 (M1L), UCM 45336 (M3U), UCM 45343 (M3U), UCM 46431 (M2L), UCM 46433 (M1L), UCM 46434 (M2L), UCM 46435 (P4L), UCM 46436 (P4L), UCM 46437 (M3U), UCM 46439 (M3U). Loc. 81032; UCM 46432 (dentary with P3-4L, M2-3L).

Palaeosyops borealis zone.- Loc. 79040; UCM 42807 (M2U), UCM 42808 (M1L), UCM 45543 (M2-3L). Loc. 79042; UCM 42196 (P4-M2L).

Discussion: The type of this species is from the Buck Spring locality (Locality 3 of Guthrie, 1971; AMNH 14664). Shoshonius cooperi differs from Loveina zephryi in the following characters: 1) metastylid developed on M1-3L; and 2) upper molars smaller with a mesostyle and less lingually expanded protocone. These specimens suggest a trend toward an increase in size of the metastylid and crenulation of the lower molars up section (through time).

Measurements: Given in Table 6.

Table 6. Tooth measurements of *Shoshonius cooperi* from the upper part of the Wind River Formation (UCM collections only).

Measurement	N	Range	$\overline{X}$	SD
P3L-L	1	-	1.60	-
P3L-W	1	-	1.50	-
P4L-L	8	1.70-2.00	1.81	0.11
P4L-W	8	1.60-1.80	1.71	0.08
M1L-L	4	1.90-2.20	2.03	0.15
M1L-W	4	1.60-1.70	1.68	0.05
M2L-L	6	1.90-2.30	2.12	0.15
M2L-W	6	1.70-1.90	1.82	0.08
M3L-L	4	-	2.70	-
M3L-W	4	1.60-1.70	1.63	0.05
M2U-L	2	-	2.10	-
M2U-W	2	2.80-2.90	2.85	0.07
M3U-L	4	1.60-1.90	1.78	0.13
M3U-W	4	2.50-2.90	2.78	0.19

Washakius Leidy, 1873

cf. Washakius sp.

Fig. 29

Referred specimen: Palaeosyops borealis zone.- Loc. 81010; UCM 46429 (P4-M2L).

Discussion: This specimen has several characters which suggest reference to Washakius rather than Shoshonius. These include a P4L with well developed labial ridge that rims the talonid basin, and lower molars with a deep talonid notch (J. Honey, oral communication, 1982) and a cristid obliquid which nearly rises up to the metaconid. The metastylid on M1-2L is barely visible, represented by a slight flexure in the postmetacristid. This specimen is the first of Washakius reported from the Wind River Formation.

Measurements: P4L-L, 2.10; P4L-W, 1.60; M1L-L, 2.30; M1L-W, 1.70; M2L-L, 2.30; M2L-W, 1.80.

Huerfanius Robinson, 1966

cf. Huerfanius sp.

Figs. 30a, 30b

Referred specimen: Palaeosyops borealis zone.- Loc. 80061; UCM 44858 (P3-4L).

Discussion: This specimen records an additional omomyid closely related to Huerfanius and Uintanius. P3L is slightly smaller than P4L as in Chlororhysis, Huerfanius and Uintanius, not as in Absarokius, Tetonius or Aycrossia. This tooth is more anteriorly

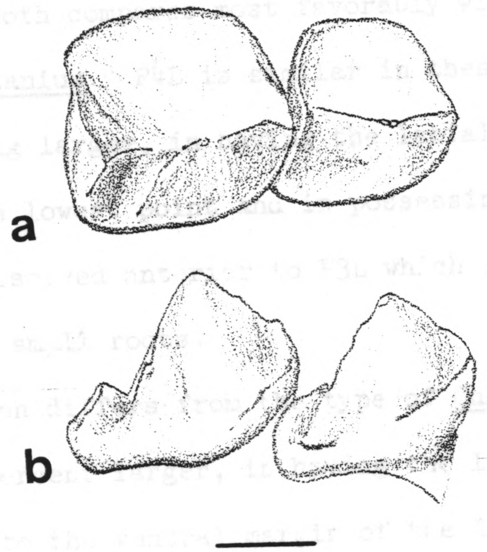

Fig. 30. Cf. Huerfanius, UCM 44858 (P3-4L); a, occlusal view, b, lingual view. Bar is 1 mm.

compressed than P4L and has a labial exodaenodont lobe. The trigonid is composed of a single large cusp with a strong anterior ridge which flexes lingually at the anterior margin of the tooth where a slight convexity hints at the presence of a paraconid. Posteriorly a strong ridge descends to the talonid. No hint of a metaconid is present. The talonid is very short with a prominent posterior ridge. In overall form the tooth compares most favorably with Chlororhysis, Huerfanius and Uintanius. P4L is similar in these characters to P3L but differs in being larger, in having the labial exodaenodont lobe more ventral at its lowest point and in possessing a small metaconid. Two alveoli are preserved anterior to P3L which indicate that these two teeth had very small roots.

The specimen differs from the type of Chlororhysis in being approximately 25 percent larger, in having the labioventral margin of P3-4L parallel to the ventral margin of the dentary, having a more exodaenodont lobe on P3-4L and in having a less obvious metaconid on P4L; otherwise they are quite similar. This specimen differs from Absarokius in having a much larger P3L in relation to P4L size, in having parallel, labioventral margins of P3L and P4L and in having a small P4L. It differs from Anaptomorphus in being larger and in having a more developed and straight exodaenodont lobe. It differs from Huerfanius in having a relatively larger P3L with well developed lobe, and from Uintanius by the less flattened crown on P3-4L. This specimen resembles Huerfanius in size, reduction of the metaconid, and more developed labial exodaenodont lobes on P3L and P4L, and is referred on that basis.

Measurements: P3-4L-L, 4.00; P3L-L, 1.70; P3L-W, 1.95; P4L-L, 2.30; P4L-W, 2.15.

Omomyidae, sp. indet.

Referred specimen: *Lambdotherium* zone.- Loc. 80062; UCM 46602 (?P2L).

Discussion: This isolated, single rooted premolar probably represents an additional species of omomyid in the Red Creek-Deadman Butte sample. It compares favorably with the P2L of *Chlororhysis knightensis* but differs in being approximately 30 percent smaller and in having a well developed postcingulid with a single median cusp. The paraconid and metaconid are absent. P2L is not known in many omomyid species; therefore, any identification would be premature.

Measurements: ?P2L-L, 1.10; ?P2L-W, 1.00.

Family Notharctidae Trouessart, 1879

Discussion: I follow Gazin (1958) in recognizing the Adapidae and Notharctidae as distinct families of Primates. Gingerich (1979, 1981b; Gingerich and Haskin, 1981) has recently reviewed the North American Notharctidae (=Notharctinae of Gingerich). He recognizes five genera of notharctid primates in the early and middle Eocene of North America: *Pelycodus*, *Cantius*, *Copelemur*, *Notharctus* and *Smilodectes*. According to his arrangement, *Pelycodus*, *Copelemur* and *Cantius* are restricted to the Wasatchian, whereas *Notharctus* and *Smilodectes* are restricted to the Bridgerian.

Cantius (=*Pelycodus* of most authors prior to Gingerich and Haskin, 1981) and *Notharctus* have been considered to be different genera in an evolving lineage (e.g., Osborn, 1902; Gregory, 1920; Gazin, 1958; Gingerich and Simons, 1977; Gingerich, 1979). The division between these genera is thus often arbitrary and based upon vague morphologic criteria which appear to change "gradually" in the fossil record. The morphologic criteria used to distinguish between these two genera has been symphysial fusion of the mandible and development of the mesostyle and pseudohypocone on the upper molars. The species of these two genera have been diagnosed on size and relative development of the mesostyle and pseudohypocone.

Pelycodus, *Copelemur* and *Smilodectes* are more easily distinguished. Gingerich and Haskin (1981) have convincingly shown that *Pelycodus* is monotypic and separate at the generic level from other notharctids. *Copelemur* is distinguished from penecontemporaneous notharctids by a deep entoconid notch on the lower molars (Gingerich and Simons, 1977). *Smilodectes* is distinguished by its squared upper molars, low paraconid, oblique metalophid, and a primitive cristid obliquid which strikes the posterior wall of the trigonid medially on M3L (Robinson, 1958). The primitive character of the cristid obliquid on M3L is also known in one species of *Notharctus*, *N. nunienus*, according to the original description of this species (Cope, 1881) and figure of the type (Osborn, 1902).

The Red Creek-Deadman Butte sample consists primarily of isolated teeth, which are extremely difficult to identify to species among notharctids (see Bown, 1982). Detailed morphologic studies of well preserved and biostratigraphically well documented samples from a number of geographic areas should help resolve this problem.

Notharctus Leidy, 1870

Discussion: This material is referred to Notharctus because the development of the mesostyle and pseudohypocone on upper molars is more consistent with characterizations of Notharctus than Cantius (=Pelycodus of Osborn, 1902 and Gazin, 1958).

Notharctus nunienus (Cope, 1881)

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 44403 (M3L).

Discussion: Cope (1881, p. 187) noted that in N. nunienus (=Pelycodus nunienum) "the external crescents of all the lower molars are well defined, but the posterior does not inclose the crown behind with an extension of its horn." Perhaps the horn refers to the position and shape of the cristid obliquid as illustrated on M3L by Osborn (Fig. 22, 1902). According to Osborn's figure of the type, the cristid obliquid strikes the base of the talonid medially rather than being directed to the protoconid as in Cantius, Pelycodus, Copelemur and all other species of Notharctus. I have not had the opportunity to examine the type of this species.

The trigonid on this specimen is high with a transverse metalophid and well developed paraconid. The cristid obliquid strikes the posterior wall of the trigonid medially, which is a primitive character also present in Smilodectes. The morphology of the trigonid and hypoconulid are similar to other specimens of Notharctus.

Measurements: M3L-L, 6.70; M3L-W, 4.05.

Notharctus sp., cf. N. venticolus

Fig. 31

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 42193 (M2L), UCM 46853 (MU), UCM 46502 (M3L). Loc. 80062; UCM 44392 (M3L fragment), UCM 44432 (M3U), UCM 46441 (M3L), UCM 46442 (M3U), UCM 46443 (P4L). Loc. 80083; UCM 45069 (M3U). Loc. 81008; UCM 46624 (M1L). Loc. 81029; UCM 46952 (M1L), UCM 46953 (M3L), UCM 46954 (M2U), UCM 46955 (M3U), UCM 46956 (M2U), UCM 46957 (M2U), UCM 46959 (M1L), UCM 46960 (M1L), UCM 46961 (M3U), UCM 46962 (M2L), UCM 46963 (M3L). Loc. 81032; UCM 47674 (fragmentary skull and right dentary with P4-M1L, M3L, and both sides P2-M3U).

Discussion: These specimens are united primarily on the basis of upper molar morphology. Lower molars are very similar to lower molars of Notharctus sp., cf. N. robinsoni. In contrast to upper molars of Notharctus sp., cf. N. robinsoni, these molars share the following characters: 1) bulbous cusps; 2) smaller pseudohypocone; and 3) smaller mesostyle. Lower molars referred here differ from the lower molar of N. nunienus in having a cristid obliquid directed to the protoconid on M3L. They differ from those of Notharctus sp., cf. N. robinsoni in being slightly smaller, but with size overlap, and in having the cusps with less pronounced crests. The

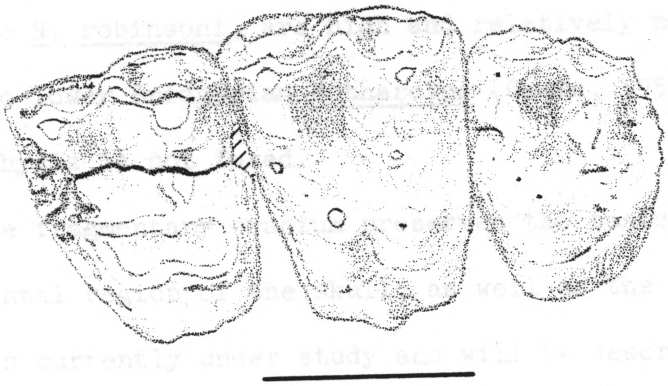

Fig. 31. Notharctus sp., cf. N. venticolus, UCM 47674 (M1-3U). Bar is 5 mm.

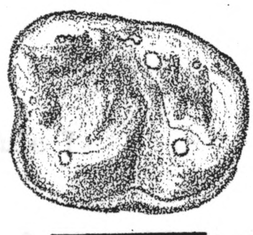

Fig. 32. Copelemur sp., near C. feretutus, UCM 46561 (M2L). Bar is 2 mm.

Fig. 33. Cf. Copelemur sp., UCM 46595 (M2L). Bar is 2 mm.

paraconids on these lower molars, as well as on those tentatively referred to N. robinsoni, are high and relatively more developed in contrast to lower Bridgerian Notharctus (Gazin, 1958). The mandibular symphysis is not fused.

The fragmentary cranium preserves the basicranium and part of the frontal region of the skull, as well as the palate. This specimen is currently under study and will be described elsewhere. Skull proportions of this specimen more closely resemble those of Bridgerian Smilodectes than they do Notharctus. The derived condition of the protoconid directed cristid obliquid on M3L, however, suggests reference to Notharctus. These specimens agree with the type of N. venticolus in size and are referred to that species on that basis.

Measurements: Given in Table 7.

Notharctus sp., cf. N. robinsoni Gingerich, 1979

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM 42801 (M2U), UCM 42802 (M2U), UCM 42804 (M3U), UCM 42806 (M3L), UCM 45240 (M2Ta), UCM 45244 (M3L), UCM 45245 (M1L). Loc. 79042; UCM 46341 (M1-2L, frontal fragment). Loc. 79043; UCM 46474 (M1-2L). Loc. 80061; UCM 44855 (M3U); UCM 46550 (symphysial region of dentary with P3L). Loc. 80065-8; UCM 46566 (M3U). Loc. 81022; UCM 46501 (M1L).

Discussion: These specimens all occur at a higher biostratigraphic level than specimens tentatively referred to N. venticolus; whether or not this arrangement is of biostratigraphic significance must

Table 7. Tooth measurements of *Notharctus* from the Wind River Formation (UCM collections only).

Measurement	*Notharctus* sp., cf. *N. venticolus*				*Notharctus* sp., cf. *N. robinsoni*			
	N	Range	$\bar{X}$	SD	N	Range	$\bar{X}$	SD
P3L-L	-	-	-	-	1	-	3.50	-
P3L-W	-	-	-	-	1	-	2.70	-
P4L-L	-	-	-	-	2	4.30-4.60	4.45	-
P4L-W	-	-	-	-	2	3.40-3.50	3.45	-
M1L-L	5	5.20-5.80	5.46	0.23	3	4.85-5.50	5.25	0.35
M1L-W	5	4.00-4.50	4.20	0.19	3	3.80-4.35	4.22	0.37
M2L-L	3	5.40-6.00	5.70	0.30	1	-	5.20	-
M2L-W	2	4.50-4.80	4.65	-	1	-	4.60	-
M3L-L	4	6.70-7.50	6.98	0.36	2	6.75-7.75	7.25	-
M3L-W	4	4.00-4.20	4.05	0.10	2	4.00-4.25	4.13	-
P2U-L	2	3.10-4.00	3.55	-	-	-	-	-
P2U-W	2	-	1.90	-	-	-	-	-
P3U-L	2	4.10-4.20	4.15	-	-	-	-	-
P3U-W	2	4.30-4.40	4.35	-	-	-	-	-
P4U-L	1	-	3.30	-	-	-	-	-
P4U-W	1	-	5.40	-	-	-	-	-
M1U-L	2	5.20-5.30	5.25	-	1	-	5.25	-
M1U-W	2	6.50-6.70	6.60	-	1	-	6.25	-
M2U-L	4	5.40-6.00	5.60	0.27	2	5.35-6.00	5.68	-
M2U-W	4	7.10-7.70	7.45	0.25	2	7.05-7.40	7.23	-
M3U-L	8	3.70-5.00	4.24	0.39	3	4.40-4.80	4.57	0.21
M3U-W	8	5.40-6.25	5.88	0.29	2	5.40-6.10	5.75	-

await more detailed studies. Lower molars can be distinguished from those in N. venticolus by stronger cristids. A tendency in the reduction of the paraconid is seen in some specimens (especially UCM 45224 and UCM 46474). Upper molars are more readily identified by the following characters: 1) crescentic cusps; 2) large pseudohypocone; and 3) large mesostyle. These specimens are tentatively referred to N. robinsoni on the basis of the characters listed above for the upper and lower molars and on their larger size.

Measurements: Given in Table 7.

Notharctus sp. A

Referred specimen: Lambdotherium zone.- Loc. 81029; UCM 46958 (M2L).

Discussion: This specimen is the largest notharctid lower molar in the sample. The trigonid has typical Notharctus morphology with the paraconid high and closely appressed to the metaconid, and an entoconid notch with a ridge of enamel connecting the entoconid and hypoconulid. This tooth compares in size to Lostcabinian notharctids from the Debeque Formation of the Piceance Basin, Colorado, currently under study by Allen Kihm (UCM).

Measurements: M2L-L, 6.30; M2L-W, 5.00 (both measurements estimated).

Copelemur Gingerich and Simons, 1977

Discussion: Gingerich and Simons (1977) named Copelemur for North American notharctids which have a deep entoconid notch. Specimens of Bridger Formation Notharctus and Smilodectes often have an entoconid notch but differ by a reduced paraconid.

The type species Tomitherium tutum (=Copelemur tutus) differs from the other species of Copelemur in having an anteriorly placed entoconid, strong entoconid-metaconid cristid, and larger size. The two species listed below are tentatively retained in Copelemur on the authroity of Gingerich and Simons (1977).

Copelemur consortutus Gingerich and Simons, 1977

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44371 (M3Tr), UCM 44675 (M3U).

Palaeosyops borealis zone.- Loc. 79042; UCM 44892 (M2U), UCM 45503 (M1Tr-2L). Loc. 79043; UCM 45510 (M2-3L). Loc. 81027; UCM 46565 (M3L).

Discussion: This species is most easily identified by small size. Lower molars of this species have a reduced paraconid, an oblique metalophid and an entoconid notch, although a ridge of enamel is present between the entoconid and hypoconulid. The cristid obliquid is directed toward the protoconid on M3L. In the combination of these characters they differ from all other notharctids in the sample.

Measurements: M2L-L (N=2), 3.85-4.10; M2L-W (N=2), 3.45-3.60; M3L-L (N=2), 4.80-5.15; M3L-W (N=2), 3.05-3.20; M2U-L, 4.20; M2U-W, 6.10; M3U-L, 3.40; M3U-W, 4.70.

Copelemur sp., near *C. feretutus* Gingerich and Simons, 1977

Fig. 32

Referred specimen: *Palaeosyops borealis* zone.- Loc. 81018; UCM 46561 (M2L).

Discussion: This specimen closely resembles the type of *C. feretutus*, an M1L (ACM 4326). This M2L is, however, larger than the type specimen. The specimen from the Red Creek-Deadman Butte area has a reduced paraconid and deep entoconid notch. This specimen differs from an M2L referred to *C. feretutus* by Gingerich and Simons (1977, ACM 11231) in size and in lack of a strong crest between the entoconid and hypoconulid. It retains a small ridge of enamel between the entoconid and hypoconulid.

Measurements: M2L-L, 4.65; M2L-W, 3.55.

cf. *Copelemur* sp.

Fig. 33

Referred specimen: *Palaeosyops borealis* zone.- Loc. 81010; UCM 46595 (M2L).

Discussion: This specimen differs in a number of characters from the M2L tentatively referred to *C. feretutus*. In morphology it is most similar to the M2L referred to *C. feretutus* (ACM 11231) by

Gingerich and Simons (1977). This specimen differs from all other Notharctids from the Red Creek-Deadman Butte area in the following characteristics: 1) basined trigonid with numerous small cuspules on the anterior rim; 2) a serpentine-shaped cristid obliquid which flexes toward the protoconid; 3) an anteroposteriorly shortened talonid; and 4) a more labial position of the hypoconid.

Measurements: M2L-L, 4.80; M2L-W, 3.75.

Smilodectes Wortman, 1903

cf. *Smilodectes* sp.

Referred specimen: *Palaeosyops borealis* zone.- Loc. 79040; UCM 44508 (M1U).

Discussion: *Smilodectes* has not been previously identified from the Wind River Formation. This isolated M1U is square in plan view. It differs from lithosympatric *Notharctus* sp., *N. robinsoni* in having a bulbous protocone and pseudohypocone, small mesostyle, weak metaconule and less crenulate enamel. However, the paracone and metacone are nearly as crescentic as in specimens referred to *N. robinsoni*. This specimen is very tentatively referred to *Smilodectes* on the basis of its square shape, reduced metaconule and similarity to lower Bridger specimens of the genus (USNM collections).

Measurements: M1U-L, 5.25; M1U-W, 6.25.

Order Taeniodonta

cf. Taeniodonta sp. indet.

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 46714 (I fragment).

Discussion: This rather large incisor fragment preserves a band of enamel with exposed dentine. It is very tentatively referred to the Taeniodonta.

Order Tillodontia

Family Esthonychidae Cope, 1883

Esthonyx Cope, 1874

Esthonyx acutidens (Cope, 1881)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44458 (MU fragment). Loc. 80063; UCM 44321 (2ML, MU fragment, unassociated). Loc. 80089; UCM 46552 (IL), UCM 45384 (P4-M1L). Loc. 81009; UCM 46397 (ML fragment).

Palaeosyops borealis zone.- Loc. 79042; UCM 46368 (MU fragment). Loc. 80101; UCM 45528 (I, MU, associated).

Discussion: Esthonyx is recognized by its primitive insectivore-like morphology, hypsodont lower molars, enlarged incisors and lack of a mesostyle on the upper molars. This material is referred to E. acutidens on the basis of size (Gazin, 1953; Guthrie, 1971). Esthonyx acutidens was the last surviving species of the genus, overlapping in time with Trogosus. McKenna (1976) has recorded Esthonyx in the upper Huerfano beds.

<u>Measurements</u>: P4L-L, 8.70; P4L-W, 5.60; M1L-L, 9.30; M1L-W, 6.00; MU-L, 9.50; MU-W, 13.50.

<u>Trogosus</u> Leidy, 1871

<u>Trogosus</u> sp. indet.

Fig. 34

<u>Referred specimens</u>: <u>Palaeosyops</u> <u>borealis</u> zone.- Loc. 79040; UCM 47717 (ML fragment). Loc. 81028; UCM 46536 (M2U).

<u>Discussion</u>: These teeth mirror their counterpart in <u>Esthonyx</u> but are more than two times larger. They are much larger than in <u>Megalesthonyx</u> and the upper molar differs in the lack of a mesostyle (Rose, 1972).

The M2U is near the size of <u>T</u>. <u>hillsi</u>, <u>T</u>. <u>castoridens</u> and <u>T</u>. <u>hyracoides</u> but cannot be referred to any of these species because of the limited diagnostic value of upper molar morphology (Gazin, 1953). <u>Trogosus</u> was an apparent immigrant into western North America, as it has been found at a number of different localities (Russell, 1935; Gazin, 1953, 1962; Robinson, 1966; Bown, 1982) with no apparent morphological intermediates between it and <u>Esthonyx</u>. Two uncataloged incisor specimens (CM collections) of <u>Trogosus</u> were collected by Hans Du Bruijn at an unknown locality in the Wind River Formation.

<u>Measurements</u>: M2U-L, 22.70; M2U-W, 36.1.

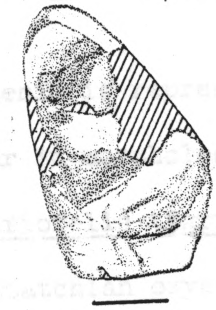

Fig. 34. Trogosus sp., UCM 46536 (M2U). Bar is 10 mm.

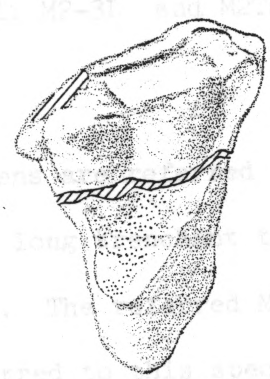

Fig. 35. Cf. Creodonta, UCM 44905 (M1U). Bar is 2 mm.

Order Creodonta

Family Oxyaenidae Cope, 1877

Oxyaenidae, sp. undetermined

Referred specimens: *Lambdotherium* zone.- Loc. 81009; UCM 46351 (P4U, M1L, PL). Loc. 81029; UCM 46910 (P4L). Loc. 81035; UCM 46510 (P4U).

Palaeosyops borealis zone.- Loc. 81022; UCM 46558 (P4U).

Discussion: A large oxyaenid is represented by this material in the fauna. The P4U is similar in morphology and near the size of *Oxyaena forcipata* and *Patriofelis tigrinus*. R. Bakker (JHU) is currently revising the Wasatchian oxyaenids and will include this material in his revision.

Family Hyaenodontidae Leidy, 1869

Prolimnocyon Matthew, 1915

Prolimnocyon antiquus Matthew, 1915

Referred specimens: *Palaeosyops borealis* zone.- Loc. 79040; UCM 42819 (dentary with alveoli M2-3L, and M2Ta). Loc. 80101; UCM 45505 (M1L).

Discussion: These specimens are referred to *Prolimnocyon antiquus* on the basis of size, the long trenchant talonids of M1L and M2L, and the single rooted M3L. The referred M1L (UCM 45505) is slightly larger than material referred to this species by Guthrie (1971) but agrees in morphology.

Measurements: M1L-L, 7.50; M1L-W, 3.80.

Prototomus Cope, 1874

cf. Prototomus sp.

Referred specimens: Lambdotherium zone.- Loc. 81029; UCM 46918 (MTr).

Palaeosyops borealis zone.- Loc. 80065; UCM 45320 (dentary with alveoli for P4-M2L, complete M3L).

Discussion: These two specimens may represent the genus Prototomus. The dentary fragment indicates that P4-M3L were nearly all the same size. The M3L has a tall trigonid with a medial paraconid. In general morphology this M3L is similar to the P. viverrinus specimen figured by Gazin (Pl. 6, Fig. 3, 1962; see Van Valen, 1965), a specimen I have not had the opportunity to examine. The ML trigonid fragment is of similar size and has the paraconid medially positioned as in the M3L. It is referred here on the basis of this similarity.

Measurements: M3L-L, 5.50; M3L-W, 3.40.

Hyaenodontidae, sp. indet.

Referred specimens: Palaeosyops borealis zone.- Loc. 79042; UCM 46370 (MTr). Loc. 79040; UCM 42841 (MTr).

Discussion: These two trigonid fragments represent an indeterminate hyaenodontid of larger size than material referred to either P. antiquus or Prototomus sp. These specimens could represent materials of Tritemnodon (Matthew, 1906) or another genus of hyaenodontid but are too fragmentary for specific generic assignment.

Creodonta, sp. indet.

Referred specimen: *Palaeosyops borealis* zone.- Loc. 79041; UCM 46345 (dentary preserving either M1L or M2L and alveoli for a molar posterior to this tooth).

Discussion: A dentary fragment preserving an M1L or M2L indicates a creodont of intermediate size. The crown of the tooth is broken. The tooth in preserved parts is robust with the talonid much shorter than the trigonid. Both *Machaeroides eothen* and *Tritemnodon agilis* display a trigonid as short as on this specimen (Matthew, 1909). The dentary and tooth are too small to be referred to *T. agilis* although the trigonid-talonid proportions are similar to this species. The jaw is more robust than in *M. eothen* and the talonid basin of the lower tooth would appear to be too short and wide for this species. The indeterminate tooth position is necessitated by the lack of any alveoli anterior to the tooth in the jaw fragment.

Measurements: MTr-L, 5.00; MTa-L, 2.50; ML-W, 4.50.

cf. Creodonta, sp. indet.

Fig. 35

Referred specimens: *Lambdotherium* zone.- Loc. 81008; UCM 44905 (M1U), UCM 46628 (anterior dentary fragment preserving base of canine, P1L, and alveoli for P2L).

Discussion: These fragmentary specimens suggest that an additional carnivorous mammal is present in the Red Creek-Deadman Butte sample. Both are referred here because they occur at the same locality and are thought to be from the same species. The dentary fragment indicates a species of small size intermediate between Viverravus lutosus and Viverravinae, gen. et sp. nov. The canine is relatively large and anteriorly projecting. P1L is small, two rooted, and has a rather flattened crown with a slightly raised anterior cusp, as occurs in Thinocyon. The P1L lies close to the P2L alveoli, suggesting a very short diastema between these two teeth. The general morphology of P1L is similar to some creodonts (for example Thinocyon Matthew, 1909); however, the fragmentary nature of this specimen precludes any positive identification.

The isolated M1U has a very small stylar area with an ectostylar ridge and no stylar cusps. The paracone is slightly taller than the metacone. Both of these cusps have a common base but diverge ventrally. The apex of each of these cusps is blunted. The parastylar area is larger than the metastylar area. Neither the preparacrista nor the postmetacrista forms a carnassial shear surface. Both conules are present but small. The protocone is high and trenchant with the preprotocrista forming a stronger shearing ridge than the postparacrista. There are no cingula.

This tooth closely resembles some early Paleocene specimens of Procerberus in the reduced stylar area and relatively trenchant protocone, and is also similar to Wyolestes (Gingerich, 1981c). It is similar to didelphodontine palaeoryctids, creodonts and didymoconids in the shared base of the paracone and metacone. In labial view this tooth resembles figures of Thinocyon (Matthew, 1909), a genus of creodont I have not seen firsthand.

These two specimens are very tentatively referred to the same taxon of creodont, primarily because of their supposed similarity to Thinocyon. Direct comparison of these specimens with paleoryctids and other primitive mammalian taxa are necessary before any confident identification can be made for these specimens. The possibility that the M1U is, in fact, a dp4U of a miacid cannot be excluded.

Measurements: M1U-L, 3.40; M1U-W, 4.00.

Order Carnivora

Family Miacidae Cope, 1880

Subfamily Viverravinae Matthew, 1909

Didymictis Cope, 1875

Didymictis altidens Cope, 1880

Referred specimens: Lambdotherium zone.- Loc. 81029; UCM 46912 (M2U), UCM 47002 (P4-M1Tr).

Palaeosyops borealis zone.- Loc. 79041; UCM 45247 (M1Ta), UCM 45248 (P3-4L).

Discussion: These specimens agree in size and morphology with specimens of D. altidens (Matthew, 1915a; Gazin, 1952; Robinson, 1966) although some are larger than the Lost Cabin Member sample of Guthrie (1971). The M2U has a somewhat reduced metacone, a character indicative of D. altidens rather than D. vancleveae (Robinson, 1966).

Measurements: P4L-L, 13.10-14.30; P4L-W, 5.80-6.70; M1Tr-L, 8.70; M1Tr-W, 9.30; M1Ta-W, 6.30; M2U-L, 5.80; M2U-W, 10.30.

Viverravus Marsh, 1872

Viverravus lutosus Gazin, 1952

Figs. 36, 37, 38

Referred specimens: Lambdotherium zone.- Loc. 81008; UCM 46640 (P4-M2L, alveoli for C-P3L). Loc. 81029; UCM 46920 (M1Tr).
Palaeosyops borealis zone.- Loc. 79040; UCM 45372 (P4L). Loc. 79042; UCM 44918 (M1L). Loc. 80092; UCM 46461 (P4U). Loc. 81022; UCM 46489 (M1L).

Discussion: Viverravus lutosus differs from lithosympatric V. gracilis in smaller size and relative reduction of the P4L (Guthrie, 1971; Gazin, 1952; see also Robinson, 1966). P1L is two-rooted. The M1L trigonid and talonid are nearly the same length and width, and the talonid is broad and basined with a trenchant hypoconid. The M2L is more than one-half the length of the M1L and has a prominent paraconid.

Measurements: P2-M2L-L, 21.30; M1-2L-L, 8.40; P4L-L (N=2), 4.60; P4L-W (N=2), 1.80-2.10; M1L-L (N=2), 4.70-5.00; M1Tr-W, 2.30-2.50; M1Ta-W, 2.00-2.40; M2L-L, 3.50; M2L-W, 2.10; P4U-L, 5.90; P4U-W, 3.00.

Viverravus sp., cf. V. gracilis Marsh, 1872

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44344 (M1U), UCM 44564 (M1U).
Palaeosyops borealis zone.- Loc. 81010; UCM 46597 (P4L).

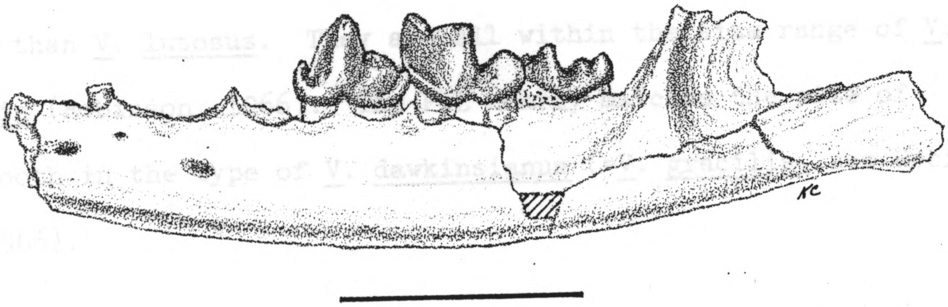

Fig. 36. Viverravus lutosus, UCM 46640 (P4-M2L). Bar is 10 mm.

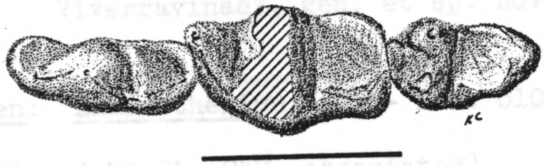

Fig. 37. Viverravus lutosus, UCM 46640 (P4-M2L). Bar is 5 mm.

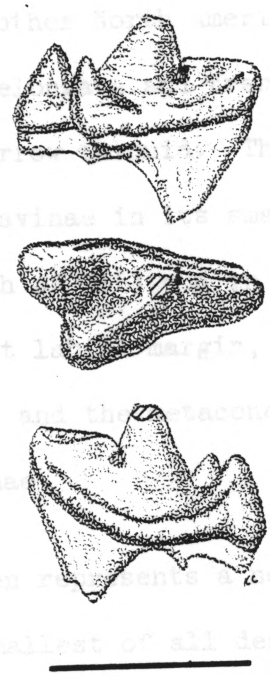

Fig. 38. Viverravus lutosus, UCM 46461 (P4U). Bar is 5 mm.

Discussion: These specimens indicate a species of Viverravus larger than V. lutosus. They are all within the size range of V. gracilis (Robinson, 1966). The P4L nearly matches the size of that tooth in the type of V. dawkinsianus (=V. gracilis, see Robinson, 1966).

Measurements: P4L-L, 5.10; P4L-W, 2.00; M1U-L (N=2), 3.60-3.80; M1U-W (N=2), 6.00.

Viverravinae?, gen. et sp. nov.

Referred specimen: Lambdotherium zone.- Loc. 81008; UCM 46639 (dentary with P2L and M1-2L, P4U, associated).

Description: The dentary indicates this species retained four lower premolars as in some Viverridae and viverravine Miacidae. The M1L differs from all M1Ls of other North American Viverravinae in having a more anteroposteriorly elongate and trenchant trigonid, anteriorly directed paraconid and narrow talonid. The M2L differs from M2L in all North American Viverravinae in its small size in relation to M1L (less than one-half length of M1L) and in the reduction of the paraconid. P4U has a straight labial margin, the protocone directly lingual to the metastyle, and the metacone large relative to other North American Viverravinae.

Discussion: This specimen represents a new genus and species of Carnivora which is the smallest of all described early to middle Eocene carnivores. The trenchant character of P4U and the M1L trigonid and relative reduction of the M2L are derived characters

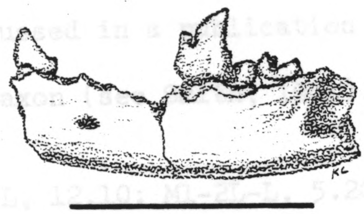

Fig. 39. Viverravinae?, gen. et sp. nov., UCM 46639 (P2,M1-2L). Bar is 10 mm.

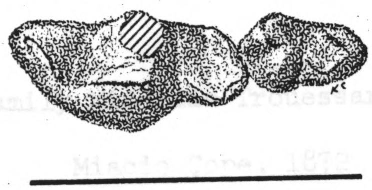

Fig. 40. Viverravinae?, gen. et sp. nov., UCM 46639 (M1-2L). Bar is 5 mm.

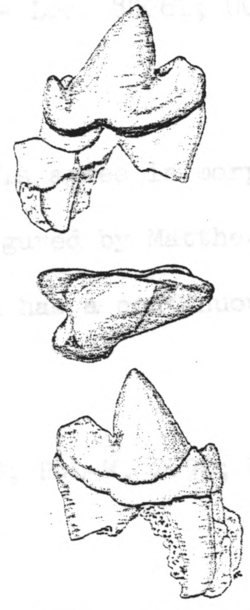

Fig. 41. Viverravinae?, gen. et sp. nov., UCM 46639 (P4U). Bar is 5 mm.

that indicate a relationship with Old World Viverridae. This specimen will be fully discussed in a publication suitable for the valid recognition of a new taxon (see Smith, 1981).

Measurements: P2-M2L-L, 12.10; M1-2L-L, 5.20; P2L-L, 1.80; P2L-W, 0.70; M1L-L, 3.50; M1Tr-W, 1.70; M1Ta-W, 1.10; M2L-L, 1.70; M2L-W, 1.00; P4U-L, 3.90; P4U-W, 2.10; depth of mandible below M1L paraconid, 3.80.

Subfamily Miacinae Trouessart, 1885

Miacis Cope, 1872

Miacis sp., cf. M. exiguus Matthew, 1915

Referred specimens: Lambdotherium zone.- Loc. 81029; UCM 46919 (M1Tr).

Palaeosyops borealis zone.- Loc. 80061; UCM 44833 (M2U). Loc. 81040; UCM 46463 (P4-M1L).

Discussion: These materials agree in morphology and size with materials of M. exiguus figured by Matthew (1915a). The M2U is relatively low crowned and has a continuous cingulum with no hypocone.

Measurements: P4L-L, 5.40; P4L-W, 2.90; M1L-L, 6.10; M1L-W, 3.50; M2U-L, 3.80; M2U-W, 5.00.

Miacis sp., cf. M. latidens Matthew, 1915

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 46697 (M1Tr). Loc. 81029; UCM 46911 (M1Tr).

Palaeosyops borealis zone.- Loc. 79040; UCM 42837 (M2L). Loc. 79041; UCM 42191 (M1L).

Discussion: These specimens are larger than specimens referred to Miacis sp., cf. M. exiguus and Miacis sp., cf. M. parvivorus and compare favorably with descriptions of M. latidens (Matthew, 1915a).

Measurements: M1L-L, 7.30; M1L-W, 4.50; M2L-L, 5.30; M2L-W, 3.90.

Miacis sp., cf. M. parvivorus Cope, 1872

Referred specimens: Lambdotherium zone.- Loc. 81031; UCM 46480 (M2U).

Palaeosyops borealis zone.- Loc. 79040; UCM 45371 (M2L). Loc. 79042; UCM 46372 (M2L).

Discussion: The posterior margin of the M2U is deeply concave, a characteristic of Miacis parvivorus noted by Robinson (1966). It is, however, smaller than the specimen discussed by Robinson. The two lower molars are referred here principally on the basis of their small size in comparison to materials referred to Miacis sp., cf. M. latidens and Miacis sp., cf. M. exiguus.

Measurements: M2L-L (N=2), 2.80-3.70; M2L-W (N=2), 2.30-2.80; M2U-L, 2.90; M2U-W, 5.30.

Oodectes Wortman, 1901

cf. Oodectes sp.

Referred specimen: Palaeosyops borealis zone.- Loc. 81027; UCM 46488 (M1U).

Discussion: This miacine M1U has equally developed metastylar and parastylar regions and is small in size. These are characters diagnostic of Oodectes (see Matthew, 1909).

Measurements: M1U-L, 3.50; M1U-W, 4.60.

Uintacyon

cf. Unitacyon sp.

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 44419 (?M3U).

Discussion: This tooth resembles an M3U referred to Uintacyon by Guthrie (1971) in its rectangular plan view, but differs from specimens of Uintacyon figured by Matthew (1909). This tooth is tentatively identified as an M3U and more tentatively assigned to Uintacyon based on its similarity to the specimen figured by Guthrie (1971).

Measurements: ?M3U-L, 3.80; ?M3U-W, 7.90.

Vulpavus Marsh, 1971

Vulpavus canavus Matthew, 1915

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 46698 (M1U), UCM 46699 (M2U), UCM 46717 (M1Ta). Loc. 81008; UCM 46921 (M1Ta-3L), UCM 46922 (M2U).

Palaeosyops borealis zone.- Loc. 79040; UCM 42824 (M2U).

Discussion: This material agrees well with described material of Vulpavus canavus (Matthew, 1915a; Guthrie, 1971). Upper and lower molars can be recognized by their crenulate crests when the teeth are unworn and by their bunodont character. The hypocone of the upper molars varies from being a small cuspule on the postcingulum to a large bulbous series of cuspules (see Fig. 16a, Guthrie, 1971).

Measurements: M2L-L, 5.70; M2L-W, 4.40; M3L-L, 4.60; M3L-W, 3.80; M2U-L (N=2), 5.10; M2U-W (N=2), 8.20-8.30.

Vassocyon Matthew

cf. Vassocyon sp.

Referred specimens: Lambdotherium zone.- Loc. 81029; UCM 46934 (M1U).

Palaeosyops borealis zone.- Loc. 79040; UCM 42847 (M1U fragment). Loc. 80061; UCM 44834 (M1U fragment).

Discussion: These specimens agree with figures of the upper molars of Vassocyon promicrodon (Fig. 36, Matthew, 1915a). They differ from other upper molars in the Red Creek-Deadman Butte area referred above to Miacis in having a cingular hypocone and a paracone much larger than the metacone.

Measurements: M1U-L, 6.50; M1U-W, 7.90.

Order Pantodonta

Family Coryphodontidae Marsh, 1876

Coryphodon Owen, 1845

Coryphodon sp. or spp.

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 46347 (radius and ulna), UCM 46350 (MU). Loc. 80062; uncataloged (head of femur). Loc. 80063; UCM 44323 (PU, tooth fragments). Loc. 80083; UCM 45066 (tooth fragments), UCM 46336 (proximal radius and femur). Loc. 81008; UCM 46661 (MU fragments). Loc. 81029; UCM 47001 (MU, tooth fragments). Loc. 81033, UCM 44954 (P3-M3L). Loc. 81034; UCM 46425 (P1L).

Palaeosyops borealis zone.- Loc. 79040; UCM 42905 (tooth fragments). Loc. 80065-5; UCM 45323 (head of femur, tooth fragments). Loc. 80090; uncataloged (postcrania).

Discussion: Coryphodon is the largest vertebrate in the fauna. Postcranial remains suggest that two species may be represented. Two heads of femora, UCM 45323 and UCM 46336, measure 60 and 83 mm in diameter, respectively; the sizes of proximal ulnae also represent two size classes. The larger specimen is known from UCM Loc. 80083, West Red Creek, the lowest locality in the sample, whereas other specimens are known from stratigraphically above this locality. This variation in size could also indicate sexual dimorphism. The sample available is too small to make a judgment on either hypothesis.

Measurements: P3L-L, 18.50; P3L-W, 15.80; P4L-L, 20.50; M1L-L, 27.50; M2L-L, 31.00; M2L-W, 25.00; M3L-L, 39.30; M3L-W, 27.00; MU-L, 27.20-31.50; MU-W, 38.10-41.50.

Order Dinocerata

Family Uintatheriidae Flower, 1876

Bathyopsis Cope, 1881

cf. Bathyopsis sp.

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 46537 (CU fragment).

Palaeosyops borealis zone.- Loc. 79040; UCM 45652 (M1U), UCM 45661 (P4L).

Discussion: The P4L has a relatively strong hypoconulid ridge and a faint but distinct entoconid resembling Probathyopsis lysitensis (Kelley and Wood, 1954) and Bathyopsis (Wheeler, 1961). These specimens are more similar in size to Bathyopsis fissidens and are referred to that genus and species on this basis.

Measurements: P4L-L, 16.90; P4L-W, 11.30; M1U-L, 15.5; M1U-W, 13.50.

Order Mesonychia

Family Mesonychidae Cope, 1875

Mesonychidae sp. indet.

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM 45231 (PL fragment). Loc. 80065-10; UCM 45362 (postcrania).

<u>Discussion</u>: The premolar indicates the presence of a mesonychid in the fauna. It is identified by its rather bulbous appearance and the ovate shape of the major cusp. There is a small anterior cusp. It is similar in size and morphology to material in the AMNH of <u>Synoplotherium</u>. The fragmentary nature of the lower premolar fragment does not permit identification below the family level.

The postcranial material is currently under study by R. Bakker, (JHU, oral communication), who has identified these materials as representing a large species of mesonychid.

Order Arctocyonia

Family Arctocyonidae

<u>Thryptacodon</u>

<u>Thryptacodon</u> <u>loisi</u> Keeley and Wood, 1954

<u>Referred specimen</u>: <u>Lambdotherium</u> zone.- Loc. 80083; UCM 45086 (M2L).

<u>Discussion</u>: <u>Thryptacodon</u> <u>loisi</u> is smaller than <u>Thryptacodon</u> <u>antiquus</u>. The trigonid on this M2L is relatively high with all three trigonid cusps prominent and isolated from one another. The paraconid is medial. The cristid obliquid descends down the anterior ridge of the hypoconid and then ascends up the posterior wall of the trigonid just lingual to the protoconid-metaconid notch. The entoconid and hypoconid are nearly equal in height. The hypoconulid is low and positioned near the entoconid. An entostylid is present in the talonid notch. A fairly strong cingulum is developed anterolabially

around the paraconid. The relatively high trigonid, medial paraconid and small size of this tooth are characters of T. loisi.

Measurements: M2L-L, 5.20; M2L-W, 3.90.

Order Condylarthra

Family Hyopsodontidae (Trouessart, 1879)

Hyopsodus Leidy, 1870

Hyopsodus wortmani Osborn, 1902

Fig. 42

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44333 (M1U), UCM 44393 (M3U), UCM 44394 (M3U), UCM 44415 (M2U), UCM 44453 (M1U), UCM 44561 (MU), UCM 45342 (MU), UCM 46797 (M1U), UCM 46799 (MTr), UCM 46801 (M1U). Loc. 80089; UCM 45392 (M1U). Loc. 81008; UCM 46643 (M2U).

Palaeosyops borealis zone.- Loc. 79040; UCM 42820 (M2U), UCM 42840 (MTr), UCM 42868 (M3L), UCM 42871 (ML), UCM 45364 (M2U), UCM 45635 (M3L), UCM 45366 (M2U), UCM 45537 (MU fragment), UCM 45552 (ML fragment). Loc. 79041; UCM 44911 (M3L). Loc. 79041; UCM 44910 (ML, dp4U, unassociated), UCM 45525 (P4-M3U). Loc. 79043; UCM 46367 (M1-2L), UCM 45502 (M2U). Loc. 81022; UCM 46496 (MTa).

Discussion: Hyopsodus wortmani is the smallest species of Hyopsodus from the upper part of the Wind River Formation. This species differs from H. paulus in the following characteristics: 1) the metastylid is very weak to absent; 2) there is no ridge between the hypoconulid and entoconid; 3) the hypoconulid is medial in position; 4) the paralophid is usually well developed; and 5) the entoconid on

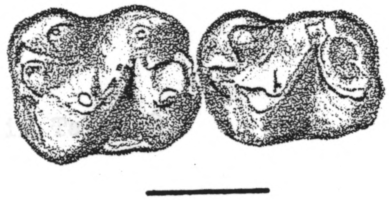

Fig. 42. Hyopsodus wortmani, UCM 46367 (M1-2L). Bar is 2 mm.

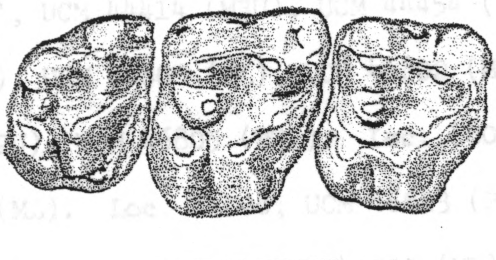

Fig. 43. Hyopsodus paulus, UCM 42189 (M1-3U). Bar is 5 mm.

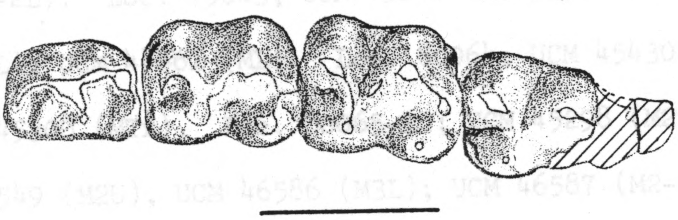

Fig. 44. Hyopsodus paulus, UCM 42189 (P4-M3L). Bar is 5 mm.

M3L is isolated. Hyopsodus wortmani resembles H. paulus in having a well developed entoconid and hypoconulid. It is not known whether these differences hold for all samples of H. wortmani. West (1973a) has noted the absence of the metastylid in the New Fork-Big Sandy sample of H. wortmani.

Measurements: Listed in Table 8.

Hyopsodus paulus Leidy, 1870

Figs. 43, 44

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 36352 (M2-3L). Loc. 80062; UCM 44328 (M1U), UCM 44329 (M2U), UCM 44332 (ML), UCM 44377 (ML), UCM 44414 (M3U), UCM 44454 (M3L), UCM 44560 (ML), UCM 45334 (MU), UCM 46800 (ML), UCM 46802 (M3L), UCM 46803 (M1U), UCM 46804 (M2U), UCM 46805 (M3L). Loc. 80063; UCM 44297 (M1-3L), UCM 44298 (ML). Loc. 81008; UCM 46623 (P4L), UCM 46642 (M3L), UCM 46644 (ML). Loc. 81029; UCM 46935 (ML), UCM 46936 (ML), UCM 46937 (M3U), UCM 46965 (M3L).

Palaeosyops borealis zone.- Loc. 79041; UCM 42189 (P3-M3L, P3L, M1-3U), UCM 42192 (M3L), UCM 46472 (M2L), UCM 46497 (M3L). Loc. 79042; UCM 42203 (P4-M3L), UCM 44909 (M2Ta-M3L), UCM 45527 (M1-2L), UCM 46366 (M1-2L). Loc. 79043; UCM 45246 (M1-2L). Loc. 80061; UCM 44831 (P4L), UCM 44861 (ML). Loc. 80064; UCM 45430 (MU). Loc. 80065-8; UCM 45300 (MTr). Loc. 80065-10; UCM 45298 (M2U). Loc. 81010; UCM 46549 (M2U), UCM 46586 (M3L); UCM 46587 (M2-3L), UCM 46588 (M1-3U), UCM 46589 (M1Ta-M2Tr), UCM 46592 (M3L), UCM 46599 (M1-2L). Loc. 81026; UCM 46473 (M3U).

Table 8. Tooth measurements of Hyopsodus wortmani from the upper part of the Wind River Formation (UCM collections only).

	Lambdotherium zone				*Palaeosyops borealis* zone			
Measurement	N	Range	$\overline{X}$	SD	N	Range	$\overline{X}$	SD
M1L-L	-	-	-	-	2	3.05-3.10	3.08	-
M1L-W	-	-	-	-	3	2.25-2.60	2.45	0.18
M2L-L	-	-	-	-	1	-	3.15	-
M2L-W	-	-	-	-	1	-	2.60	-
M3L-L	-	-	-	-	3	3.80-4.00	3.88	0.10
M3L-W	-	-	-	-	3	2.40-2.65	2.55	0.13
dp4U-L	-	-	-	-	1	-	3.80	-
dp4U-W	-	-	-	-	1	-	3.70	-
P4U-L	-	-	-	-	1	-	2.40	-
P4U-W	-	-	-	-	1	-	3.40	-
M1U-L	5	3.40-3.65	3.52	0.12	1	-	3.00	-
M1U-W	5	4.00-4.90	4.42	0.35	1	-	3.75	-
M2U-L	3	3.45-3.50	3.47	0.03	6	3.00-3.70	3.40	0.24
M2U-W	3	4.40-4.60	4.70	0.36	5	4.10-5.00	4.61	0.45
M3U-L	2	2.80-3.20	3.00	-	1	-	2.70	-
M3U-W	2	-	4.30	-	1	-	3.65	-

Discussion: No prior discussion of Wind River Formation Hyopsodus has referred any specimens to H. paulus. Most recent workers have referred the species intermediate in size between H. wortmani and H. walcottianus to H. miticulus, the now lost type of which is from the San Juan Basin of New Mexico (Gazin, 1968; Guthrie, 1971). This set of specimens displays a common morphological pattern that differs from other intermediate and small species of Hyopsodus in the sample, and suggests that all of these specimens should be referred to the same species. The characters in common include: 1) a P4L with a well developed metaconid, hypoconulid and entoconid; 2) molars with a large and cuspate entoconid; 3) the hypoconulid well developed, posterior and more lingual than in H. wortmani and H. minusculus and more medial than in Hyopsodus sp. indet.; and 4) the M3L hypoconulid has well developed ridges that connect to the entoconid and hypoconid in most specimens. Specimens from the Lambdotherium zone differ from specimens from the Palaeosyops borealis zone in being somewhat smaller and having a smaller metastylid (a character which is probably a function of allometry). Otherwise the morphology of the lower molars is similar in specimens from both zones. Reference of upper molars to this species is based on size, as no readily apparent differences in upper molar morphology could be distinguished. These specimens are referred to H. paulus on the basis of the following criteria: 1) they show no discernable differences from the type of H. paulus or referred middle Eocene specimens other than those characters related to size; 2) similarity in size to samples of H. paulus (Gazin, 1968); 3) they agree in characters listed above with H. paulus: and 4) the now lost type specimen of H. miticulus is probably of much older age (late Graybullian to Lysitean Land Mammal subage, see Lucas et al., 1981). Now that excellent biostratigraphically well documented collections of Hyopsodus are available from a number of different basins (Gingerich, 1976; West, 1979), it should be possible to reapply the methodological approach of Olson and Miller (1958) to sort out the variation patterns in Hyopsodus. This type of analysis could prove to be quite instructive in the delineation of variation patterns through both time and space.

Measurements: Listed in Table 9.

Hyopsodus sp., cf. H. minusculus Leidy, 1871

Referred specimen: Palaeosyops borealis zone.- Loc. 80065-5; UCM 45303 (M1L).

Discussion: This single newly erupted M1L displays no wear facets. The paraconid is a small but well defined cusp. The entoconid and hypoconulid are both well developed. A metastylid is also present. Overall the tooth has a more hypsodont appearance than any other tooth in the sample, although this may be more a function of the lack of wear than a true difference in morphology. This tooth closely resembles material from the Bridger Formation which has been referred to H. minusculus in the USNM collections in having a relatively tall gracile hypoconulid.

Measurements: M1L-L, 4.00; M1L-W, 3.00.

Table 9. Tooth measurements of Hyopsodus paulus from the upper part of the Wind River Formation (UCM collections only).

	Lambdotherium zone				Palaeosyops borealis zone			
Measurement	N	Range	X̄	SD	N	Range	X̄	SD
P4L-L	1	-	3.50	-	3	3.35-3.65	3.47	0.16
P4L-W	1	-	2.50	-	3	2.50-2.75	2.65	0.13
M1L-L	5	3.60-4.30	3.92	0.28	6	3.50-4.30	4.01	0.27
M1L-W	5	2.95-3.30	3.10	0.14	6	2.90-3.80	3.35	0.31
M2L-L	4	3.60-4.50	4.10	0.42	9	3.80-4.60	4.24	0.25
M2L-W	4	3.25-3.60	3.45	0.15	9	3.30-3.85	3.65	0.17
M3L-L	6	4.00-5.25	4.63	0.42	6	4.40-5.50	4.70	0.40
M3L-W	6	2.65-3.50	3.08	0.27	7	3.10-3.55	3.32	0.16
M1U-L	2	3.90-3.95	3.93	-	3	3.90-4.20	4.07	0.15
M1U-W	2	4.90-5.00	4.95	-	3	5.00-5.15	5.05	0.09
M2U-L	2	4.10-4.35	4.23	-	2	4.00-4.55	4.28	-
M2U-W	2	5.50-6.00	5.75	-	2	5.55-5.85	5.70	-
M3U-L	2	3.30-3.60	3.45	-	6	3.40-4.10	3.71	0.25
M3U-W	2	4.70-4.80	4.75	-	6	3.80-5.20	4.80	0.53

Hyopsodus walcottianus Matthew, 1915b

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 43717 (MU, much of enamel lacking).

Discussion: Hyopsodus walcottianus is distinguished from all other Lambdotherium zone Hyopsodus by its much larger size (Robinson, 1966; Gazin, 1968). It is quite probable that H. walcottianus evolved from H. powellianus and may merely be the end member of an anagenetic series that became larger. H. walcottianus is restricted to the Lambdotherium zone, apparently becoming extinct before the immigration of either Palaeosyops or Hyrachyus.

Hyopsodus, sp. indet.

Referred specimens: Palaeosyops borealis zone.- Loc. 79041; UCM 42197 (P4-M2L). Loc. 81010; UCM 46590 (M2Ta-M3L).

Discussion: These two specimens cannot be confidently referred to any currently recognized species of Hyopsodus. They differ from all other Hyopsodus specimens in the Red Creek-Deadman Butte sample in the following characteristics: 1) the entoconid and hypoconulid are small cusps and are not connected by a ridge of enamel; 2) the hypoconulid is lingual and closely appressed to the entoconid; 3) on P4L the metaconid is not well developed and the talonid is simple; 4) on M3L the hypoconulid is isolated with no ridges of enamel connecting it to the hypoconid and entoconid; and 5) the size is intermediate between H. wortmani and H. paulus (near the size of H. minusculus). The metastylid is present, though weaker than in comparably sized H. paulus. UCM 42197 is lithosympatric with specimens referrable to H. paulus and H. wortmani, whereas UCM 46590 is lithosympatric with H. paulus. The character differences listed above appear to be derived in the construction of the lower molar talonids but primitive in P4L construction. These two specimens probably indicate an additional species of Hyopsodus that is comparatively rare in the upper part of the Wind River Formation. At present the morphological differences are sufficient to indicate a distinct species.

Measurements: P4L-L, 2.70; P4L-W, 2.60; M1L-L, 3.70; M1L-W, 2.80; M2L-L, 3.70; M2L-W, 2.95; M3L-L, 3.90; M3L-W, 2.60.

Family Phenacodontidae Cope, 1881

Phenacodus Cope, 1873

Phenacodus vortmani (Cope, 1880)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 46735 (MU fragment). Loc. 81008; UCM 47024 (MU fragment), UCM 47023 (M2L).

Discussion: Phenacodus vortmani is most easily confused with Ectocion superstes, a phenacodontid which occurs lithosympatrically with P. vortmani. Phenacodus vortmani is distinguished in the upper dentitions by its quadrate molars and well developed cusps and conules. In lower dentitions P. vortmani is distinguishable by the lack of an entostylid and a cusp on the central portion of the cristid obliquid in the Wind River Formation sample. Phenacodus vortmani is distinguished from P. primaevus by its smaller size.

Measurements: M2L, 8.00; M2L-W, 6.80.

Phenacodus primaevus Cope, 1873

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44348 (MU fragments), UCM 44455 (MLTr), UCM 45345 (ML fragments), UCM 46731 (P4L). Loc. 81008; UCM 46641 (P4-M1L). Loc. 81030; UCM 46424 (P3-M3L).

Discussion: Phenacodus primaevus is distinguished from P. vortmani by its larger size, more bunodont and crenulate molars, and thicker enamel. West (1976) advocated the reference of all large Wasatchian Phenacodus to P. primaevus. Both Bown (1979a) and Rose (1981) have suggested that this conclusion may not be warranted, a conclusion with which I agree. Although specimens of P. primaevus from the upper part of the Wind River Formation are rare, all are very similar in morphology and do not encompass the range of morphology of West's concept of P. primaevus. Perhaps a multivariate analysis, taking into account good stratigraphic and geographic data, would help resolve the difficulties involved in Phenacodus primaevus evolution.

Measurements: P3L-L, 9.20; P3L-W, 5.70; P4L-L, 9.90-11.10; P4L-W, 7.20-8.00; M1L-L, 10.30-11.40; M1L-W, 9.70-10.50; M2L-L, 11.40; M2L-W, 10.00; M3L-L, 10.30; M3L-W, 9.00; M3U-L, 11.20; M3U-W, 10.60.

Ectocion Cope, 1882

Ectocion superstes Granger, 1915

Referred specimen: Palaeosyops borealis zone.- Loc. 79041; UCM 45388 (M3U).

Discussion: Dentary remains of Ectocion superstes can be distinguished from Phenacodus primaevus, the species with which it is most likely to be confused, by the transverse and rectangular M1-2U, triangular and bunodont M3U, and lower molars with an entostylid and mesoconid. Ectocion superstes is the most common phenacodontid from the Davis Ranch locality (Locality 1 of Guthrie, 1971). As far as known, no specimens are found in the Lambdotherium zone, suggesting that E. superstes may have been an immigrant into the northeastern part of the Wind River Basin from some unknown prior range in North America (Ectocion is a common genus in Clarkforkian and early Wasatchian assemblages).

Measurements: M3L-L, 6.20; M3U-W, 9.10.

Order Perissodactyla

Family Equidae Gray, 1821

Discussion: Three genera of early and middle Eocene North American equids are currently recognized: Hyracotherium Owen, 1840; Orohippus Marsh, 1872; and Xenicohippus Bown and Kihm, 1981. Xenicohippus is known from Wasatchian rocks of the Bighorn, Piceance, and Huerfano Basins and differs from the other two genera in P2-3L morphology. Isolated molars of Xenicohippus are extremely difficult to distinguish from Hyracotherium. Xenicohippus is not represented in the Red Creek-Deadman Butte collections from the upper part of the Wind River Formation.

Kitts (1956, 1957) most recently reviewed the species of Hyracotherium and Orohippus. Hyracotherium is known only from Wasatchian rocks, whereas Orohippus has previously been recorded only from the Bridgerian and Uintan. Kitts (1957, p. 5) distinguished Orohippus from Hyracotherium by the following characteristics:

1. P^3 and P^4 with four major cusps of roughly equal size;
2. Upper molars with mesostyle and with ectoloph V-shaped between paracone and metacone;
3. P_3 with entoconid;
4. P_4 with entoconid about as large as other cusps;
5. Heel of M_3 always relatively shorter than in Hyracotherium.

Most researchers who have dealt with equid samples of latest Wasatchian to earliest Bridgerian age have commented, either directly or implicitly, on the variation of characters which are suggestive of Orohippus in samples that were referred to Hyracotherium and vice versa (Granger, 1908; Kitts, 1956, 1957; Robinson, 1966; West, 1973a). Kitts (1957) suggested that O. pumilus may have evolved from H. vasacciense and O. major may have evolved from H. craspedotum (see also Guthrie, 1971). I have assessed the specimens in this sample according to the criteria established by Kitts. This results in the documentation of Orohippus and Hyracotherium from the upper part of the Wind River Formation. I have also attempted to delineate additional criteria that may be of use in determining the different taxa when a sample of isolated teeth is available. These criteria are based solely on specimens referred here and discussions of other researchers. Upper molars are more amenable to taxa separation than are lower molars, and some of the latter may prove to have been assigned to the wrong taxon. Future studies incorporating more completely preserved specimens will no doubt tend to eliminate this error.

Gingerich (1981b) has presented the hypothesis that some populations of Hyracotherium tapirinum (=H. craspedotum of Kitts, 1956) were sexually dimorphic in tooth morphology. The sample of isolated teeth is too limited to reassess this hypothesis.

Hyracotherium Owen, 1840

Hyracotherium craspedotum Cope, 1880

Referred specimens: Lambdotherium zone.- Loc. 79045; UCM 42032 (M1U), UCM 42033 (ML), UCM 42035 (M3L). Loc. 80062; UCM 44387 (M3U), UCM 44428 (dp4U), UCM 44430 (M1U), UCM 44431 (P3U), UCM 44436 (ML), UCM 44898a (P4U), UCM 46733 (ML, M3L, unassociated), UCM 46734 (M2U), UCM 46739 (M3U), UCM 46743 (M3U). Loc. 81008; UCM 47015 (2P4U), UCM 47017 (2M2U, M3U, unassociated), UCM 46401 (M3Ta), UCM 47019 (P4L). Loc. 81029; UCM 46941 (2M1U), UCM 46970 (ML).

Discussion: The type of H. craspedotum was collected from the Wind River Formation by Jacob L. Wortman in 1880. This seems the most appropriate name for the Wind River Basin specimens referred here, although specimens formerly referred to H. craspedotum from the Huerfano Basin (Kitts, 1956) have been informally referred to H. tapirinum (Gingerich, 1981b). H. craspedotum from the study area differs from H. vasacciense in the following characteristics:

1) upper and lower molars are more bunodont and crenulate with

cingula well developed; 2) P4U is simple and as described by Kitts (1956); 3) on the upper molars the premetaconule crista does not generally intersect the base of the metacone, a mesostyle is usually developed, the conules are more bulbous and the labial side of the metacone is less convex; 4) on the lower molars the hypoconulid is more cusp-like than ridge-like and on M3L the hypoconulid is nearly as high and cuspate as the entoconid and hypoconid; and 5) H. craspedotum is larger than H. vasacciense.

Hyracotherium craspedotum differs from cf. Orohippus sp. in the following characteristics: 1) the upper molar mesostyles are less developed; 2) the enamel is more crenulate; 3) P4L is simple and as described by Kitts (1956); 4) the hypoconulid of M3L is much larger; and 5) H. craspedotum is considerably larger than cf. Orohippus sp.

If H. craspedotum and O. major prove to be synonymous, which seems to be a quite tenable arrangement, I would refer the species to Hyracotherium because of the simple premolar morphology (see Kitts, 1956). This would necessitate accepting the character convergence of mesostyle development and V-shaped centrocristae (Kitts, 1957). H. craspedotum is common in the Lambdotherium zone and uncommon in the Palaeosyops borealis zone. A few specimens from the Davis Ranch locality (Locality 1 of Guthrie, 1971) are preserved in the Carnegie Museum collections.

Measurements: Listed in Table 10.

Table 10. Tooth measurements of Hyracotherium from the upper part of the Wind River Formation (UCM collections only).

	Hyracotherium craspedotum				Hyracotherium vasacciense			
Measurement	N	Range	X̄	SD	N	Range	X	SD
P2L-L	-	-	-	-	1	-	6.50	-
P2L-W	-	-	-	-	1	-	3.20	-
P3L-L	-	-	-	-	2	6.80- 7.00	6.90	-
P3L-W	-	-	-	-	2	4.10- 4.20	4.15	-
P4L-L	1	-	7.00	-	3	6.40- 7.20	6.90	0.44
P4L-W	1	-	5.20	-	3	4.50- 4.90	4.70	0.20
M1L-L	1	-	8.70	-	3	7.20- 7.70	7.43	0.25
M1L-W	1	-	6.20	-	3	4.90- 5.20	5.07	0.15
M2L-L	3	9.50-10.00	9.83	0.29	4	7.60- 8.80	8.10	0.50
M2L-W	3	7.20- 7.60	7.37	0.21	4	5.10- 6.00	5.50	0.37
M3L-L	2	12.40-13.30	12.85	-	2	10.20-11.10	10.75	-
M3L-W	2	-	6.70	-	2	5.20- 5.40	5.30	-
P2U-L	-	-	-	-	1	-	6.10	-
P2U-W	-	-	-	-	1	-	4.70	-
P3U-L	-	-	-	-	1	-	6.70	-
P3U-W	-	-	-	-	1	-	7.30	-
P4U-L	-	-	-	-	1	-	6.80	-
P4U-W	-	-	-	-	1	-	8.60	-
M1U-L	3	9.10- 9.60	9.23	0.32	9	7.20- 8.50	7.78	0.37
M1U-W	3	10.90-11.30	11.10	0.20	9	7.90- 9.80	9.13	0.74
M2U-L	3	7.90- 9.50	8.67	0.80	6	7.70- 8.20	8.00	0.21
M2U-W	3	8.80-11.70	10.63	1.59	6	9.20-10.90	9.92	0.69
M3U-L	3	8.60- 9.50	9.20	0.53	6	7.50- 8.10	7.83	0.27
M3U-W	3	10.10-11.50	10.93	0.74	6	8.80-10.00	9.27	0.43

Hyracotherium vasacciense (Cope, 1872)

Fig. 45

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 46355 (M2U). Loc. 79045; UCM 42036 (M3L), UCM 45380 (MU, P4U, unassociated). Loc. 80062; UCM 44330 (M1U), UCM 44395 (P4L), UCM 44399 (M1U), UCM 44413 (M3U), UCM 44416 (ML), UCM 44427 (ML), UCM 44898 (ML), UCM 45330 (ML), UCM 46736 (M2U), UCM 45330 (ML), UCM 46740 (ML), UCM 46742 (dp4L), UCM 46744 (ML fragment), UCM 46881 (MU fragment), UCM 46996 (M3U). Loc. 80063; UCM 46304 (M1-2U), UCM 44307 (ML), UCM 44309 (MU fragment), UCM 44311 (MU fragment), UCM 44312 (M1U), UCM 44313 (M3), UCM 44314 (MU fragment), UCM 45373 (MU fragment). Loc. 80083; UCM 45065 (M3U). Loc. 80089; UCM 45387 (M3U). Loc. 81008; UCM 47020 (2M2U, M1U, M3U, unassociated). Loc. 81009; UCM 46396 (M1U). Loc. 81029; UCM 46940 (P3L, M1U, M3U, unassociated), UCM 46941a (MU fragment), UCM 46973 (P2-M3U, M1U, associated). Loc. 81031; UCM 46404 (P3-4L, M2-3L), UCM 46564 (MU fragment). Palaeosyops borealis zone.- Loc. 79041; UCM 45385 (M2U), UCM 46344 (P2L, P4-M3L), UCM 46346 (M1-2L). Loc. 80064; UCM 46395 (MTr). Loc. 81010; UCM 46544 (M1-2L).

Discussion: H. vasacciense differs from both H. craspedotum and cf. Orohippus sp. in the Red Creek-Deadman Butte sample by the following characteristics: 1) both upper and lower molars are more cuspate and higher crowned; 2) on the upper molars the conules are more evident when the tooth is worn, the premetaconule crista connects at the base of the metacone, and there is no mesostyle; and 3) the hypoconulid is more ridge-like on M1-2L and is relatively larger on

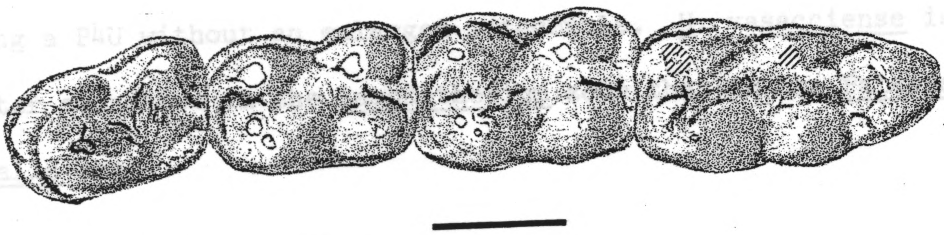

Fig. 45. Hyracotherium vasacciense, UCM 46344 (P3-M3L). Bar is 5 mm.

Fig. 46. Cf. Orohippus sp., UCM 44897 (M3U). Bar is 2 mm.

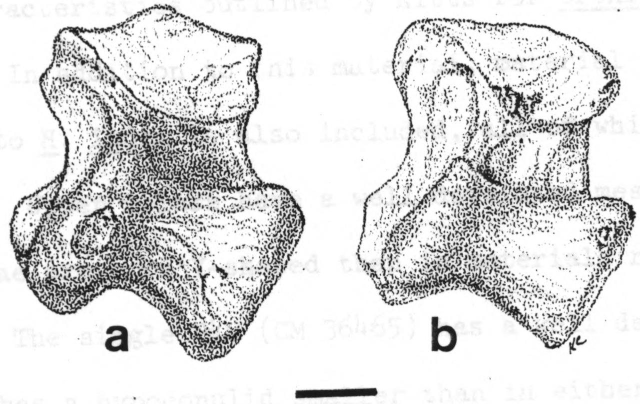

Fig. 47. Astragali of Palaeosyops borealis (a, UCM 46458) and Hyrachyus sp., cf. H. eximius (b, UCM 45660). Bar is 10 mm.

M3L. H. vasacciense differs from H. craspedotum in more complex upper and lower premolars, a flattened hypoconulid on M3L and smaller size. It differs from cf. Orohippus sp. in being larger and in having a P4U without an enlarged metaconule. H. vasacciense is in greater abundance in the Lambdotherium zone than in the Palaeosyops borealis zone.

Measurements: Given in Table 10.

Orohippus Marsh, 1872

cf. Orohippus sp.

Referred specimens: Lambdotherium zone.- Loc. 79045; UCM 44897 (M3U), UCM 42034 (P4U). Loc. 80063; UCM 44305 (P4L).
Palaeosyops borealis zone.- Loc. 79040; UCM 42832 (M1U), UCM 42833 (M3L), UCM 42829 (MTa), UCM 42896 (ML), UCM 45229 (M1U fragment). Loc. 79042; UCM 46465 (M3U fragment). Loc. 80061; UCM 44832 (M2U); Loc. 81047; UCM 46417 (M1U, M3U, unassociated).

Discussion: In preserved materials, this set of specimens conforms more to the characteristics outlined by Kitts for Orohippus than for Hyracotherium. In addition to this material, material referred by Guthrie (1971) to H. index is also included, all of which are from his Locality 4. Upper molars have a well developed mesostyle and the centrocristae are more V-shaped than in materials referred to Hyracotherium. The single P4U (CM 36465) has a well developed hypocone. M3L has a hypoconulid smaller than in either H. vasacciense or H. craspedotum. This species is also smaller than either species of Hyracotherium, although larger specimens overlap the size range of H. vasacciense.

The single M3U (UCM 44897) from Loc. 79039 has a mesostyle more developed than any other M3U in the sample. This is curious, as this represents the lowest stratigraphic occurrence for the species. The size of these specimens is similar to the Orohippus sp. material from the Aycross Formation reported by Bown (1982). If the specimens from the Red Creek-Deadman Butte area are correctly referred, this represents the earliest known occurrence of the genus Orohippus in North America.

Measurements: Given in Table 11.

Family Palaeotheriidae Gill, 1872

Lambdotherium Cope, 1880

Lambdotherium popoagicum Cope, 1880

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 42195 (MU), UCM 45394 (MU). Loc. 79045; UCM 42037 (dp3U), UCM 42039 (M2L), UCM 45374 (MU). Loc. 80062; UCM 44340 (MU fragment); UCM 44396 (MU fragment), UCM 44420 (P3U), UCM 44421 (P2U), UCM 44422 (MU), UCM 44435 (M2L), UCM 46730 (P4L), UCM 46747 (MU fragment), UCM 46748 (M1L), UCM 46749 (MU fragment), UCM 46750 (M3Ta), UCM 46751 (MU), UCM 46752 (MU fragment). Loc. 80063; UCM 44318 (M1L, MU, unassociated), UCM 44325 (P3L). Loc. 80089; UCM 45390 (MU fragment). Loc. 81008; UCM 47016 (P4L, M1L, M2L, dp4U, unassociated). Loc. 81009; UCM 46399 (2MU, unassociated). Loc. 81029; UCM 46938 (MU), UCM 46939 (2ML fragments, M3L, unassociated), UCM 46971 (P3U), UCM 46972

Table 11. Tooth measurements of cf. Orohippus sp. from the upper part of the Wind River Formation (UCM collections only).

Measurement	N	Range	$\overline{X}$
P4L-L	1	-	6.35
P4L-W	1	-	4.40
ML-L	1	-	7.80
ML-W	2	5.00-5.60	5.30
M3L-L	1	-	8.80
M3L-W	1	-	4.80
P3U-L	1	-	5.95
P3U-W	1	-	6.20
M1U-L	3	6.50-6.70	6.56
M1U-W	2	7.20-8.00	7.60
M2U-L	1	-	6.70
M2U-W	1	-	7.80
M3U-L	2	6.90-7.30	7.10
M3U-W	2	-	8.50

(2P4L, unassociated). Loc. 81034; UCM 46408 (MU fragment). Loc. 81035; UCM 46559 (MU fragment).

Discussion: Wallace (1980) has recently reviewed the genus Lambdotherium and transferred it to the Palaeotheriidae. He has concurred with the conclusion of Bonillas (1936) that this genus is monotypic, all materials being referred to Lambdotherium popoagicum. Wallace has documented the morphology of this species in detail.

Guthrie (1967) and Korth (1982) have both referred fragmentary isolated teeth to Lambdotherium which were recovered from Lysite Member strata. Neither of these authors cited specimen numbers nor figured the specimens. I have not had the opportunity to examine the specimen identified as Lambdotherium by Guthrie (1967). The two specimens identified from the Lysite Member as Lambdotherium by Korth (1982, CM 37017) are both M3L talonids. These specimens are probably referrable to the equid Xenicohippus (Bown and Kihm, 1981). They differ from all lower third molars of Lambdotherium examined in the following characteristics: 1) small size (CM 37017, M3Ta-W, (6.40-6.70); 2) hypolophid not complete and transverse; and 3) hypoconulid trenchant, dorsally wedge-shaped and relatively less wide than hypolophid. In contrast, Lambdotherium M3L has the following characteristics: 1) larger size (M3Ta-W, 7.95); 2) hypolophid complete and oblique; and 3) hypoconulid lobe-shaped, flattened and nearly as wide as hypolophid.

Lambdotherium popoagicum has long been known to have a restricted biostratigraphic range but widespread geographic occurrence. When it occurs in a fossiliferous horizon it is usually one of the most abundant taxa. The recognition that Lambdotherium and Palaeosyops are not lithosympatric allows for the clarification of the age relationships of many fossil vertebrate localities close in age to the Wasatchian-Bridgerian boundary (Chapter IV). I could not confidently identify the tooth position of upper molars.

Measurements: P3L-L, 8.80; P3L-W, 6.00; P4L-L (N=3), 9.20-9.90; P4L-W (N=3), 6.50-6.90; M1L-L (N=3), 11.00-11.90; M1L-W (N=3), 7.80-8.30; M2L-L (N=3), 12.60-13.40; M2L-W (N=3), 8.80-9.60; M3L-L, 12.50; M3L-W, 9.00; dp3U-L, 8.60; dp3U-W, 8.10; P2U-L, 7.00; P2U-W, 6.00; P3U-L, 8.20; P3U-W, 9.80; MU-L (N=8), 10.90-12.80; MU-W (N=8), 12.90-17.20.

Family Brontotheriidae Marsh, 1873

Palaeosyops Leidy, 1870

Palaeosyops borealis Cope, 1880

Fig. 47a

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM 42836 (P3L), UCM 42882 (P4-M3U, association uncertain), UCM 45232 (MU fragment), UCM 44900 (P3U fragment). Loc. 79041; UCM 45249 (P3-M1U fragment). Loc. 80065-5; UCM 45306 (P3U). Loc. 79042; UCM (ML fragment). Loc. 80090; UCM 46551 (P2L, ML fragment, M3L associated). Loc. 81010; UCM 46337 (P4-M3L). Loc. 81017; UCM 46458 (astragalus). Loc. 81048; UCM 46338 (M2L).

Discussion: Wallace (1980) has recently reviewed the first titanotheres of the North American Eocene. The fossil material referred to Palaeosyops borealis agrees in both size and morphology with his characterization of that species. No new information can be added to his descriptions. Despite the low frequency of occurrence of P. borealis at most localities (minimum number of individuals is usually one), remains of this animal are usually part of the first surface collection from a fossiliferous horizon because of its large size. Palaeosyops borealis is not lithosympatric with Lambdotherium popoagicum in the Red Creek-Deadman Butte sample. Because of this, I advocate that the Wasatchian-Bridgerian boundary be based on the first occurrence of titanotheres as well as other taxa as discussed in Chapter IV.

Measurements: P4L-L, 11.80; P4L-W, 8.20; P2L-L, 11.60; P2L-W, 5.60; M1L-L, 15.70; M1L-W, 10.50; M2L-L, 16.60-18.50; M2L-W, 12.20-12.60; M3L-L, 21.70-23.80; M3L-W, 12.20-12.80.

Family Helaletidae Osborn, 1892

Heptodon Cope, 1882

Discussion: Radinsky (1963) was the most recent researcher to review the Wasatchian material of the genus Heptodon. He recognized two species, H. calciculus (Cope, 1880) and H. posticus (Cope, 1882). He synonymized H. ventorum (Cope, 1880) with H. calciculus, and H. brownorum (Seton, 1931) with H. posticus. Research currently in progress (with L. Krishtalka, CM) suggests that the synonomy of H. ventorum with H. calciculus is unwarranted and that the diversity of late Wasatchian and early Bridgerian helaletid tapiroids is much greater than previously supposed. This suggestion is based on newly recovered biostratigraphically well documented tapiroid specimens which occur at high abundance and in lithosympatry, and a reexamination of both Wasatchian and Bridgerian materials in view of this hypothesis.

Heptodon calciculus (s.s. the type, AMNH 4858, and specimens nearly identical to the type from the Wind River Formation in the USNM collections) differs from H. ventorum (type, AMNH 4850 and referred specimens) in the following characteristics: 1) P1L is absent (present in H. ventorum); 2) the metalophid and hypolophid are skewed at an approximate 15 degree angle from the axis of the mandible, especially the hypolophid on M3L (these lophids are transverse in H. ventorum); 3) the entoconid is rounded (in H. ventorum the entoconid has a strong anterior ridge); 4) the hypoconulid on M3L is very small (in H. ventorum the hypoconulid on M3L is large); 5) the enamel is smooth (H. ventorum has crenulate enamel); and 6) H. calciculus is generally smaller than H. ventorum. These characteristics are correlated in the same specimens. Associated upper and lower jaw material suggests that the upper molars can be distinguished as well by the following characters: 1) H. ventorum has a small labially convex metacone on M3U, whereas H. calciculus has a posteriorly elongate and labially concave metacone on M3U; 2) the paraloph and metaloph are posteriorly concave in H. calciculus and straight in H. ventorum; 3) H. calciculus has smooth enamel and H. ventorum has crenulate enamel; and 4) H. calciculus is generally smaller than H. ventorum.

The type of H. calciculus (AMNH 4858) is nearly identical to materials of Bridgerian age referred to Helaletes nanus in the USNM collections examined, suggesting that Heptodon calciculus Cope is a junior synonym of Helaletes nanus Marsh. Fortunately Heptodon ventorum is the type species of Heptodon.

In favor of the specific distinction of H. ventorum from H. nanus is their biostratigraphic occurrence and frequency of occurrence. Specimens of H. ventorum in the Lambdotherium and Palaeosyops borealis zones are common, whereas only one molar talonid is referrable to H. nanus, which is from the Palaeosyops borealis zone.

A new unnamed species of Heptodon is also represented from the Wind River Formation Palaeosyops borealis zone. This rare species is closely related to H. ventorum but is much smaller (smaller than H. nanus as well, but larger than Selenaletes scopaeus), and has a more lophiodont and higher crowned dentition. Two specimens are known from the Davis Ranch locality; CM 30999, an isolated lower molar, and AMNH 17562, associated upper and lower dentitions. This species occurs in lithosympatry with an abundant sample of H. ventorum at the Davis Ranch locality and with H. nanus at the Someday locality (UCM Loc. 79040). Additional specimens probably referrable to this species are known from the Knight fauna (UCMP 43703, Gazin, 1962; Radinsky, 1963) and from the Huerfano Formation (AMNH 17562, AMNH 55262).

Heptodon posticus is the largest in size of all species within the present concept of the genus Heptodon. It is characterized by the same derived characteristics of H. nanus but is much larger and has a larger hypoconulid on M3L. While size is of some importance in distinguishing H. posticus, it overlaps somewhat with H. ventorum as does this latter species with H. nanus.

The arrangement of these species into a single genus Heptodon is probably polyphyletic. Helaletes nanus, H. posticus and Hyrachyus form a monophyletic clade, some members of which are sister taxa to the rhinos, and H. ventorum and Heptodon n. sp. are only somewhat derived over the isectolophid Homogalax and represent an early Eocene radiation of that group.

Heptodon ventorum (Cope, 1880)

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 46354 (M2U). Loc. 80062; UCM 46754 (MTr). Loc. 81029; UCM 46942 (M3U), UCM 46967 (4MTr, M3Ta, unassociated).

Palaeosyops borealis zone.- Loc. 79042; UCM 42817 (M1-2L). Loc. 79043; UCM 46340 (palate preserving LP3-M3U, RP2-M3U, and dentary with P4L, associated). Loc. 80065-5; UCM 45319 (M2U, P4Ta-M2Tr, associated).

Discussion: The morphology of this species has been discussed above. Well preserved and abundant specimens of this species from Guthrie's Locality 1 (Davis Ranch, UCM Locs. 79042 and 79043) and Locality 3 (Buck Spring, UCM Locs. 79029-79033) are preserved in the Carnegie Museum and American Museum of Natural History collections, respectively. This is by far the most common tapiroid from the upper part of the Wind River Formation. This species is also known from the Bridger Formation (Bridger B, M1-3L, USNM field no. 66-59). Gazin (1952, 1962) was correct in referring much of his sample to H. ventorum rather than H. calciculus.

Measurements: P4L-L, 8.20; P4L-W, 6.60; M1L-L (N=3), 9.40-9.60; M1L-W (N=3), 6.90-7.10; M2L-L, 10.10; M2L-W, 7.50; M3L-L, 7.50; P2L-L, 5.00; P2U-W, 5.80; P3U-L (N=2), 6.80-7.00; P3U-W (N=2), 8.30-8.50; P4U-L (N=2), 7.50-7.80; P4U-W (N=2), 9.60-9.70; M1U-L (N=2), 8.40-8.90; M1U-W (N=2), 11.20-11.40; M2U-L (N=6), 9.80-12.00; M2U-W (N=6), 11.30-13.30; M3U-L (N=4), 9.40-13.60; M3U-W (N=4), 12.00-14.30.

Heptodon n. sp., near Heptodon ventorum (Cope, 1880)

Referred specimen: Palaeosyops borealis zone.- Loc. 79040; UCM (M2U).

Discussion: This M2U is smaller than most M2Us of Heptodon ventorum and is higher crowned and more lophiodont than the latter species. The upper molars of this species are readily distinguished from those of Helaletes nanus in having a straight, rather than curved, protoloph and metaloph.

Measurements: M2U-L, 8.70; M2U-W, 9.60.

Heptodon? posticus Cope, 1882

Referred specimens: Lambdotherium zone.- Loc. 79039; UCM 44893 (MTr, M3Ta, unassociated). Loc. 79045; UCM 42038 (M3U). Loc. 80062; UCM 44429 (M3Ta). Loc. 81029; UCM 46968 (P3L, P4L, unassociated). Loc. 81035; UCM 46413 (P4L, M2L, unassociated).

Discussion: Although no specimens are recorded from the Palaeosyops borealis zone in UCM Red Creek-Deadman Butte collections, this species is known from the Davis Ranch locality where H. ventorum is abundant (CM collections).

Measurements: P3L-L, 8.90; P3L-W, 6.20; P4L-L (N=2), 6.50-8.00; M2L-L, 12.10; M2L-W, 7.90; M3Ta-W, 7.50; M3U-L, 12.20; M3U-W, 14.50.

Helaletes Marsh, 1872

Helaletes nanus (Marsh, 1871)

Probable synonym: Heptodon calciculus (Cope, 1880)

Referred specimen: Palaeosyops borealis zone.- Loc. 79040; UCM 45647 (M3Ta).

Discussion: The M3Ta referred here has a very small hypoconid, a character diagnostic of this species (see discussion above).

Measurements: M3Ta-W, 6.70.

Hyrachyus Leidy, 1871

Hyrachyus sp., cf. H. eximius Leidy, 1871

Fig. 47b

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM 44895 (IL, P2L, ML, M2U, M3U, all fragmentary but probably associated), UCM 45228 (MTr), UCM 45660 (astragalus). Loc. 81048; UCM 46335 (CL, P3L, ML, scapula and carpal elements, associated).

Discussion: Radinsky (1967) has referred all lower Bridger and Wind River Formation Hyrachyus to H. modestus, despite a bimodal size distribution. New specimens from several areas with relatively well documented biostratigraphic information have been recovered since Radinsky's review (West, 1973a; Bown, 1982). The fragmentary specimens reported here are quite large; in fact, some exceed those of the lower Bridger sample reported by Radinsky. The bimodal size distribution indicates that two species are represented. This is also evident when specimens of _Hyrachyus_ from the Huerfano and New Fork-Big Sandy areas are considered. Reference to _Hyrachyus_ sp., cf. _eximius_ is based primarily on size.

The inclusion of _Hyrachyus_ in the Helaletidae is one of utility, as _Hyrachyus_ appears to be more closely related to rhinos than to either _Heptodon ventorum_ or _Helaletes nanus_ (Krishtalka and Stucky, in preparation). _Hyrachyus_ sp., cf. _H. eximius_ is distinguished from all other helaletids by its large size, relatively well developed lingual cristid obliquid and miniscule hypoconulid on the lower molars, especially M3L. The astragalus of _Hyrachyus_ can be distinguished from _Palaeosyops borealis_ by its relatively shorter neck and broader trochlea (both are approximately the same size) (Fig. 47).

Measurements: P3L-L, 10.50; P3L-W, 6.30; ML-L, 18.80, MTa-W, 12.20; M2U-L, 22.10; M2U-W, 25.50.

Order Artiodactyla

Family Dichobunidae (Turner, 1849)

Discussion: Revision of middle to late Eocene North American dichobunids is currently in progress (Krishtalka and Stucky, in progress), and only a few preliminary comments are presented. The most recent revision of Wasatchian and Bridgerian members of this family from North America was published by Sinclair in 1914, although Gazin (1955) commented extensively on these mammals in his review of the late Eocene artiodactyls. Most discussions of the Wasatchian and Bridgerian artiodactyls since Sinclair's review have been included in either faunal studies (e.g., Gazin, 1952, 1962, 1976; McKenna, 1960; Guthrie, 1967, 1971; Bown, 1979a) or in papers relating to the origin of the artiodactyls (e.g., Van Valen, 1971; Rose, 1982). Both Van Valen (1971) and Guthrie (1967, 1971) have informally suggested the synonomy of early Eocene species and genera without figuring specimens or presenting detailed morphologic comparisons and discussion. Detailed discussions are needed to asses the validity of these synonomies before they are formally recognized.

Diacodexis Cope, 1882

Discussion: Diacodexis is a well represented but poorly understood Eocene dichobunid genus. Guthrie (1967) briefly commented on the species of this genus. Two species of Diacodexis are represented in the Red Creek-Deadman Butte sample, including Diacodexis sp. A (=D. metsiacus in part, Guthrie, 1971) and Diacodexis olseni (considered a junior synonym of D. secans by Guthrie, 1967, 1971).

Diacodexis sp. A

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44401 (MU), UCM 44423 (M1L), UCM 44696 (M1L), UCM 46810 (M3L).
Palaeosyops borealis zone.- Loc. 79041; UCM 46508 (M1L).

Discussion: Specimens of Diacodexis sp. A found in the Lost Cabin Member have formerly been referred to D. metsiacus (Guthrie, 1971). Examination of specimens referred to D. metsiacus from the Wind River Formation, Willwood Formation, and Almagre and Largo of New Mexico display a variation in morphology that is difficult to accept for a single species. Variation of P3L, P4L, and the trigonid of the lower molars is especially pronounced. Relations of P3L and P4L vary from P3L being shorter to its being one and one-half times the length of P4L. The height of the major cusp and general character of these premolars also varies. They may have a very sharp dominant cusp or a low one. A paraconid may be developed or it may not. These teeth may be quite bunodont or relatively sectorial. On the lower molars of specimens referred to D. metsiacus the paraconid may be either well separated on all three molars, well separated only on M1L, or nearly coalesced with the metaconid on all three lower molars. The protoconid may be the same height as the paraconid and metaconid or just a fraction over half the height of these two cusps. This morphologic variation could indicate different lithosympatric taxa living at the same time, an evolving lineage or simply an extremely variable species. The determination of which hypothesis best fits the data must await detailed studies of biostratigraphically well documented lithosympatric specimens.

Diacodexis sp. A can be distinguished from D. olseni in this sample by its relatively shorter P3L, relatively higher P4L major cusp, more distinct paraconid on lower molars (especially on M1L), relatively square upper molars with a small, less bunodont protocone, strong pre- and postcingulum and smaller size.

Measurements: M1L-L (N=3), 4.00-4.30; M1L-W (N=3), 3.20-3.30; M3L-L, 5.50; M3L-W, 3.80; MU-L, 4.10; MU-W, 4.90.

Diacodexis olseni Sinclair, 1914

Fig. 48

Referred specimens: *Lambdotherium* zone.- Loc. 80062; UCM 44341 (M3U), UCM 44457 (MU), UCM 45346 (MU), UCM 46809 (MU), UCM 46811 (MU). Loc. 81008; UCM 47026 (M3L).

Palaeosyops borealis zone.- Loc. 79041; UCM 42199 (P3-M3L). Loc. 79042; UCM 44906 (MU), UCM 45516 (?dp4U). Loc. 81010; UCM 46582 (P3L). Loc. 81027; UCM 46808 (?dp4U).

Discussion: Guthrie (1967) synonymized *D. olseni* with *D. secans*. The type of *D. secans* (AMNH 4899) is from an unknown locality in the Wind River Basin and the type of *D. olseni* (AMNH 14937) is from the Davis Ranch locality (Locality 1 of Guthrie, 1971), where this species is well represented. The type of *D. olseni* differs from the type of *D. secans* in having more robust and square lower molars (Table 12) and better developed paraconids. The specimens referred to *D. olseni* more closely agree with the type of that species than the type of *D. secans* and are referred on that basis. The characters distinguishing *D. olseni* and *Diacodexis* sp. A were discussed above under the latter species. The most readily distinguishable characters of *D. olseni* are the robust, bunodont P4L and robust protocone on the bunodont upper molars. The two dp4Us referred here are almost identical in morphology to the upper molars. They may,

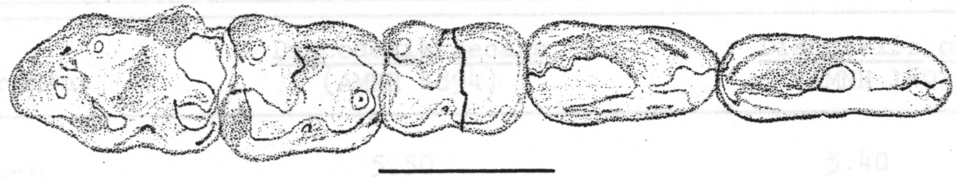

Fig. 48. Diacodexis olseni, UCM 42199 (P3-M3L). Bar is 5 mm.

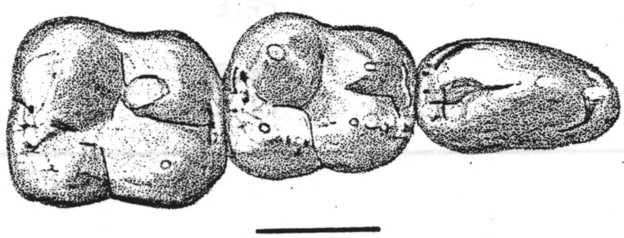

Fig. 49. Bunophorus sinclairi, UCM 42188 (P4-M2L). Bar is 5 mm.

Fig. 50. Antiacodon pygmaeus, UCM 45235 (M1U). Bar is 2 mm.

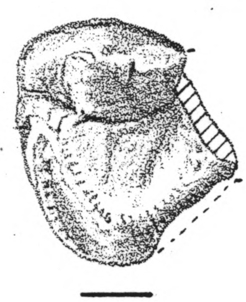

Fig. 51. Helohyus sp., cf. H. plicodon, UCM 46477 (MTa). Bar is 2 mm.

Table 12. Tooth measurements of the type specimens of Diacodexis secans and Diacodexis olseni. Measurements are maximum widths and lengths except where indicated.

Measurement	Diacodexis secans (AMNH 4894)	Diacodexis olseni (AMNH 14937)
P4L-L	5.50	5.40
P4L-W	2.60	3.20
M1L-L	4.25	4.50
M1L-W	3.40	4.00
M2L-L	4.50	4.75
M2L-W	3.95	5.00 (Ta)
M3L-L	5.65	-
M3L-W	3.75	4.70 (Tr)

however, be upper permanent molars of a small species of Diacodexis closely related to D. olseni.

Measurements: P3L-L (N=2), 6.70-7.00; P3L-W, 2.20-2.40; P4L-L, 5.90; P4L-W, 3.00; M1L-L, 4.50; M1L-W, 3.50; M2L-L, 4.50; M2L-W, 4.30; M3L-L (N=2), 6.60-6.80; M3L-W (N=2), 4.20-4.40; MU-L (N=2), 4.40; MU-W (N=2), 5.70-6.00; M3U-L, 4.60; M3U-W, 6.60.

Bunophorus Sinclair, 1914

Discussion: Both Bunophorus and Wasatchia (probably also including Sarcolemur crassus, q.v. Cope, 1877) are recognizable genera of bunodont artiodactyls (see Robinson, 1966). To the best of my knowledge, Wasatchia is not known later than the Lysitean subage, where it reaches its most derived development in Wasatchia lysitensis.

Two species of Bunophorus are recognized in the Red Creek-Deadman Butte sample: Bunophorus sinclairi (=B. gazini and in part B. etsagicus of Guthrie, 1971) and Bunophorus sp. A. The two species are known to occur in lithosympatry at the Deadman Butte locality (UCM Loc. 80062). Bunophorus sp. A is the smaller and is very rare, especially in the Palaeosyops borealis zone.

Bunophorus sinclairi Guthrie, 1966

Fig. 49

Probable synonym: Bunophorus gazini Guthrie, 1971.

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 46807 (M2L). Loc. 81008; UCM 47025 (M3L). Loc. 81029; UCM 46981 (M3U). Palaeosyops borealis zone.- Loc. 79041; UCM 42188 (P4-M2L).

Discussion: The type specimens of Bunophorus sinclairi (PU 13448) and Bunophorus gazini (CM 22483) were both recovered from the "maroon shale" layer at Davis Ranch. The only difference is size. A large number of specimens in the Carnegie Museum collections from the same fossiliferous horizon show intergradation between the two type specimens. All have morphological characters discussed by Guthrie (1966, 1971) which distinguish this species from B. etsagicus including: 1) more bunodont cusps; 2) loss of the cristid obliquid; 3) nearly equal height of trigonid and talonid in unworn specimens; 4) hypoconulid reduced; and 5) talonid noticeably wider than trigonid. Bunophorus sinclairi differs from Bunophorus sp. A primarily in being larger and having more bunodont cusps.

Measurements: P4L-L, 7.70; P4L-W, 7.50; M1L-L, 7.60; M1L-W, 6.50; M2L-L (N=2), 7.70-8.20; M2L-W (N=2), 6.50-7.20; M3L, 9.90; M3L-W, 6.30; M3U-L, 7.00; M3U-W, 10.00.

Bunophorus sp. A

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44409 (M1L), UCM 46806 (M1L).
Palaeosyops borealis zone.- Loc. 79040; UCM 43018 (M3L). Loc. 80065-5; UCM 45308 (MU).

Discussion: This second species of Bunophorus from the Red Creek-Deadman Butte sample is similar in morphology but smaller in size than B. sinclairi. It can be identified by its smaller size, more crenulate enamel, more prominent paraconid, larger hypoconulid and mound-like cusps. These specimens do not fit readily into any named species of Bunophorus. They are larger than in B. macropternus and smaller than either B. etsagicus or B. sinclairi.

Measurements: M1L-L (N=2), 7.40-6.80; M1L-W, 5.60-6.00; M3L-L, 8.80; M3L-W, 6.10; MU-L, 6.70; MU-W, 7.20.

Antiacodon Marsh, 1872

Antiacodon pygmaeus (Cope, 1872)

Fig. 50

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM 42866 (MTr), UCM 43046 (P4L), UCM 45235 (M1U).

Discussion: Lower molars of Antiacodon can be distinguished from all other dichobunids in the sample by a more lingual paraconid, anteriorly convex paralophid, and strong cristid obliquid which rises up the posterior wall of the trigonid and connects directly to the metaconid. Upper molars can be distinguished by: 1) their strong conules, which are, in occlusal view, as large as the paracone and metacone; 2) small medial protocone; and 3) well developed cingula and square shape. A. pygmaeus and A. vanvaleni are probably both valid species, based principally on the upper molars (Krishtalka and Stucky, unpublished data). A. pygmaeus differs from A. vanvaleni in having a large cingular hypocone, which is lacking in the latter species. Antiacodon is restricted to the Palaeosyops borealis zone.

Measurements: P4L-L, 5.50; P4L-W, 3.20; M1U-L, 4.10; M1U-W, 5.00.

Helohyus Marsh, 1872

Helohyus sp., cf. H. plicodon Marsh, 1872
Fig. 51

Referred specimen: Palaeosyops borealis zone.- Loc. 79043; UCM 46477 (MTa).

Discussion: This fragmentary talonid of an unerupted lower molar is referred to Helohyus on the basis of the following characters: 1) well developed entoconid; 2) lingual, poorly developed hypoconulid which is located on the postcingulid and connected to the hypoconid by a ridge; 3) a deep ectoflexid; and 4) bunodont cusps. To the best of my knowledge this is the earliest record of Helohyus. Reference to H. plicodon is based on size (Sinclair, 1914).

Measurements: MTa-W, 6.80.

Order Rodentia

Discussion: The rodent materials collected in 1979 and 1980 from the Red Creek-Deadman Butte area have been thoroughly discussed by Korth (1981). His identifications (written communications, 1981) are listed below. Materials collected during the 1981 field season were compared to the materials identified by Korth and his concepts of the variability within each species were used for identification. Here only specimen numbers are reported for each taxon from each locality.

Paramys copei Loomis, 1907

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44327, UCM 44369, UCM 44372, UCM 44390, UCM 44397, UCM 44406, UCM 44407, UCM 44424, UCM 44434, UCM 44720, UCM 44731, UCM 45331, UCM 46665, UCM 46670, UCM 46674, UCM 46678. Loc. 80063; UCM 44322. Loc. 80089; UCM 45386. Loc. 81008; UCM 46633. Loc. 81029; UCM 46668, UCM 46925-46932. Loc. 81035; UCM 46414.

Palaeosyops borealis zone.- Loc. 79040; UCM 42843, UCM 42859-42860, UCM 42863, UCM 44907, UCM 45219-45220, UCM 45524, UCM 45538, UCM 45540. Loc. 79041; UCM 46513, UCM 46540. Loc. 79042; UCM 44908, UCM 45521, UCM 46470. Loc. 79043; UCM 42198, UCM 46471. Loc. 80061; UCM 44848-44851, UCM 45254, UCM 46567. Loc. 81010; UCM 46583. Loc. 81022; UCM 46520. Loc. 81048; UCM 46520.

Paramys excavatus Loomis, 1907

Referred specimen: Lambdotherium zone.- Loc. 80062; UCM 44726

"Paramys" francesi Wood, 1962

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44727, UCM 46666-46667, UCM 46669, UCM 46671, UCM 46676.

Palaeosyops borealis zone.- Loc. 79042; UCM 46371. Loc. 79043; UCM 42220-42221. Loc. 80061; UCM 44846-44847. Loc. 81027; UCM 46677.

?Thisbemys sp.

Referred specimen: Palaeosyops borealis zone.- Loc. 79040; UCM 42848.

Microparamys sp.

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44712, UCM 44725, UCM 46673, UCM 46691.

"Mysops" kalikola Matthew, 1918

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44365, UCM 44714, UCM 45352, UCM 46684.

Palaeosyops borealis zone.- Loc. 80061; UCM 44836.

Knightomys depressus (Loomis, 1907)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44359, UCM 44368, UCM 44703, UCM 44706, UCM 44715, UCM 44718, UCM 45327-45328, UCM 45358, UCM 46683, UCM 46685-46686. Loc. 80083; UCM 45068. Loc. 81008; UCM 46638.

Palaeosyops borealis zone.- Loc. 79040; UCM 42825, UCM 42857, UCM 45218, UCM 45221, UCM 45225. Loc. 79041; UCM 46524. Loc. 80061; UCM 44837, UCM 44841, UCM 44844-44845. Loc. 81022; UCM 46483, UCM 46521.

Knightomys huerfanensis (Wood, 1962)

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44707, UCM 44723, UCM 46682.

Palaeosyops borealis zone.- Loc. 79040; UCM 42852, UCM 42854, UCM 45224. Loc. 79041; UCM 45420. Loc. 80061; UCM 45281.

Knightomys senior (Gazin, 1952)

Referred specimens: Palaeosyops borealis zone.- Loc. 79040; UCM 42823. Loc. 80061; UCM 44839, UCM 45253, UCM 45277, UCM 46886. Loc. 81022; UCM 46519.

Pauromys sp.

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44373, UCM 44708-44711, UCM 44713, UCM 44734, UCM 46680, UCM 46688-46690. Palaeosyops borealis zone.- Loc. 80061; UCM 44842, UCM 45358-45259, UCM 45270, UCM 45292-45293.

Family Ischyromyidae sp. indet.

Referred specimens: Lambdotherium zone.- Loc. 80062; UCM 44352, UCM 46672. Loc. 81008; UCM 46632, UCM 46634, UCM 46636-46637. Palaeosyops borealis zone.- Loc. 79040; UCM 45544. Loc. 79043; UCM 45532. Loc. 80061; UCM 44843.

Discussion: These specimens do not readily fit into any of the above rodent species, and represent a heterogenous assemblage that may be placed into one or more species. Specimens from the Viverravus locality (UCM Loc. 81008) probably represent an additional species of Paramys not recorded from other localities in the Red Creek-Deadman Butte area. These specimens are intermediate in size between P. copei and P. francesi, and are more bunodont than most specimens assigned to either of these taxa.

Order uncertain

Suborder Palaeanodonta Matthew, 1918

Palaeanodonta sp. A

Referred specimens: Palaeosyops borealis zone.- Loc. 80061; UCM uncataloged (proximal humerus). Loc. 80065-14; UCM 45317 (proximal humerus).

Discussion: Ken Rose (written communication, 1981) has examined a cast of UCM 45317. He notes that the specimen is similar to the humerus of Epoicotherium and Xenocranium, and may represent Tetrapassalus, a Bridger species known only from a few fragmentary jaw remains (West, 1973c). The small size of the two humeri is consistent with the size of Tetrapassalus jaw remains.

Palaeanodonta sp. B

Referred specimen: Palaeosyops borealis zone.- Loc. 81018; UCM 46695 (dentary fragment lacking teeth).

Discussion: This dentary fragment retains a single rounded alveolus for the ultimate molar and a rugose bone pattern on the labial side of the dentary. The single socketed ultimate molar and bone pattern are suggestive of the Palaeanodonta. If correctly referred, this specimen indicates a second palaeanodont species as it is too large to be associated with the two humeri referred to Palaeanodonta sp. A.

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Appendix A. Measured Sections, Wind River Formation.

An asterisk to the left of the unit number indicates that the unit is a vertebrate fossiliferous horizon. The locality number is given in parentheses following the unit description. Thicknesses are given in feet and meters (in parentheses). Hand samples for many units are in the locality collections of the University of Colorado Museum. For more detailed information on fossiliferous horizons, see Appendix B.

Red Creek Stratigraphic Section

Measured Section 1. Red Creek stratigraphic section, section of Wind River Formation and Middle (?) Eocene sequence. Measured at Wind River Formation contact on Mowry Shale, Sec. 17, T. 38 N., R. 87 W. to SE ¼ Sec. 25, T. 38 N., R. 88 W. General east-west strike; dip 4-6 degrees south.

Quaternary alluvium:

92. Gravel, poorly sorted, cobble to boulder, clast supported 3.0 (0.9)

Unconformity

Middle (?) Eocene Volcaniclastic Sequence:

*91. Paraconglomerate, brown, massive, poorly sorted, matrix supported; very fine to course grained matrix; pebble to cobble size clasts, well rounded volcaniclastics (basalts) and claystone balls; some minor lentiles of mudstones and carbonaceous shales; silicified wood logs; fossil vertebrates rare, some well rounded bone fragments, randomly distributed in unit; unit faulted to south against Wind River Formation (UCM Loc. 80064-C). 80.0 (24.4)

90. Carbonaceous shale, moderate yellowish brown (10 YR 5/4), tabular, thinly laminated parallel to bedding plane; leaf impressions, sharp lower contact 4.5 (1.4)

*89. Mudstone, pale olive green (10 Y 6/2), tabular, sharp lower contact, more than 95% clay with subangular quartz; calcite and gypsum crystals, spheroidal barite crystal clusters; aquatic fossil vertebrates 7.0 (2.1)

Wind River Formation, Lost Cabin Member:

Upper Gray Sequence:

88.	Paraconglomerate, dusky yellow (5 Y 6/4), massive, matrix medium to coarse quartz and rock fragments, micaceous; quartzite pebbles, matrix supported; top of unit well sorted medium to coarse rock fragments, micaceous; calcareous cannonball concretions; top of unit with iron oxide cement.	39.5 (12.0)
87.	Mudstone, light greenish gray (5 GY 8/1), silty, poorly exposed	18.0 (5.5)
86.	Mudstone, light greenish gray (5 GY 8/1), silty, poorly exposed	31.0 (9.5)
85.	Sandstone, yellow gray (5 YR 4/1), crossbedded; fine to medium subrounded quartz and rock fragments; conglomeratic at base; calcareous cannonball concretions; carbonaceous shale lentiles with leaf impressions; fossil logs in place at 10.0 ft. (3.0 m) above base (UCM Loc. 80102). . .	82.0 (25.0)
84.	Mudstone, yellowish gray (5 Y 7/2), silty	15.0 (4.6)
83.	Mudstone, pale red-gray mottled, silty; weathers red	12.0 (3.7)
*82.	Mudstone, greenish gray (5 GY 6/1), micaceous, well rounded quartz grains; coprolites and turtle shell fragments, lepisosteid scales (UCM Loc. 80103).	7.0 (2.1)
81.	Sandstone, greenish brown, fine to coarse grained, pebble conglomerate in part	4.0 (1.2)
80.	Mudstone and sandstone, poorly exposed.	18.0 (5.5)
79.	Mudstone, mottled pale red-gray, silty; some fine to medium quartz sand.	4.0 (1.2)
78.	Mudstone, pale olive (10 Y 6/2), sand and silt increase towards top of unit.	7.0 (2.1)
77.	Sandstone, light gray (N-7), very fine, muddy . .	11.0 (3.4)
76.	Mudstone and sandstone, greenish gray (5 GY 6/1), micaceous (10% of volume), pedotubules and calcareous glaebules.	10.0 (3.0)

75.	Claystone, greenish gray, calcareous; sharp lower contact	2.0 (0.6)
74.	Mudstone, gray, laminated; sharp contact below. .	7.0 (2.1)
73.	Claystone, very light gray (N-8) to medium light gray (N-6), alternating laminations; mud volcano structures, excellent marker bed, tabular unit, sharp contact below	3.0 (0.9)
72.	Mudstone, light greenish gray (5 GY 8/1), silty; some very fine grained quartz sand; becomes coarser towards top of unit; sharp lower contact.	8.0 (2.4)
71.	Sandstone, light gray, micaceous, calcareous, poorly sorted, muddy, graded and laminated bedding; angular to subangular fine to coarse grains; intraformational mudstone and calcareous glaebule pebbles and abundant biotite crystals at base; sharp lower contact.	8.5 (2.6)
70.	Mudstone, light gray (N-7), silty, micaceous; becomes coarser grained toward top of unit; sharp contact with lower unit	3.0 (0.9)
69.	Mudstone, greenish gray (5 GY 6/1), silty, micaceous, laminated, some angular claystone clasts at base; sharp contact with lower unit . .	3.0 (0.9)
68.	Mudstone, greenish gray (5 GY 6/1), silty; some rhizoliths.	2.0 (0.6)
67.	Mudstone, medium gray	2.0 (0.6)
66.	Mudstone, light gray; poorly exposed.	37.0 (11.3)
65.	Mudstone, green, silty.	2.0 (0.6)

Variegated Sequence:

64.	Mudstone, red-green mottled	2.0 (0.6)
63.	Sandstone, greenish gray (5 GY 7/1), very fine grained, micaceous.	11.0 (3.4)
62.	Mudstone, grayish yellow-green (5 GY 7/2), silty, bioturbated; nonpreferentially cemented pedotubules, noncarbonized leaf and small invertebrate impressions	5.0 (1.5)

*61.	Mudstone, red-green mottled; sandy to silty, calcareous pedotubules and glaebules, non-preferentially cemented pedotubules, coprolites, eggshell fragments, silicified plant (very rare), abundant turtle and crocodile remains, mammals common; lower part of unit is a green silty mudstone which grades to red-green mottled mudstone, to brick red-gray mottled mudstone with abundant calcareous glaebules at top (Someday locality, UCM Loc. 79040).	8.0 (2.4)
60.	Sandstone, yellowish gray, fine to medium grained, subangular rock fragments, well sorted, crossbedded; conglomeratic at base; clasts of Precambrian quartzites and schists, Flathead Formation sandstones and conglomerates and Paleozoic limestones and dolomites; shoestring channel geometry channeled into lower units . . .	9.0 (2.7)
59.	Mudstone, grayish red (5 R 4/2)-green mottled, sandy, calcareous; large light gray calcareous glaebules	6.0 (1.8)
58.	Claystone, light greenish gray (5 GY 8/1), abundant calcareous glaebules (25% of volume); small burrows	3.5 (1.1)
57.	Mudstone, light greenish gray (5 G 8/1), sandy. .	3.5 (1.1)
56.	Mudstone, grayish yellow-green (5 GY 7/2), silty, calcareous in part; some fine sand; calcareous glaebules distributed in horizontal planes, calcareous pedotubules; abundant microvertebrates consisting of relatively complete elements (Lightning Butte, UCM Loc. 80061)	5.5 (1.7)
55.	Mudstone, light greenish gray (5 GY 8/1), highly calcareous; some very fine grained sand; calcareous glaebules	3.0 (0.9)
54.	(Number inadvertantly omitted)	
53.	Sandstone, grayish yellow-green (5 GY 7/2), fine grained, micaceous, well sorted rock fragments; highly calcareous	2.5 (0.8)
52.	Sandstone, grayish yellow-green (5 GY 6/2), fine to medium grained, muddy, tabular geometry. . . .	2.0 (0.6)
51.	Mudstone, light greenish gray (5 G 8/1), sandy. .	5.0 (1.5)

50.	Sandstone, yellowish gray (5 Y 8/1), medium to coarse grained, calcareous; preferentially cemented, ironstone concretions, calcite crystals; channeled into lower units.	4.0 (1.2)
49.	Mudstone, gray; calcareous glaebules.	10.0 (3.0)
48.	Sandstone, yellowish gray (5 Y 7/2), crossbedded, micaceous, calcareous; fine to medium grained; lower 0.5 ft. (0.2 m) resistant; ironstone concretions	6.0 (1.8)
47.	Claystone and mudstone, light greenish gray (5 GY 8/1), laminated bedding, slightly calcareous.	11.0 (3.4)
46.	Mudstone, red-green mottled, silty; laterally loses red color shifting to gray; calcareous glaebules	3.0 (0.9)
45.	Sandstone, yellowish gray (5 Y 7/2), medium grained, subangular, well sorted, calcareous, coarsens upward into pebble conglomerate, channeled into lower units.	7.0 (2.1)
44.	Mudstone, light greenish gray (5 GY 8/1), sandy, micaceous, calcareous	4.0 (1.2)
*43.	Mudstone, red-green mottled; coprolites	3.0 (0.9)
42.	Sandstone, yellowish gray (5 Y 7/2), very fine to medium grained, poorly sorted, calcareous, resistant	5.0 (1.5)
41.	Sandstone, light green (5 GY 6/1), very fine to fine grained, muddy; some dark yellowish orange streaks (10 YR 6/6)	11.0 (3.4)
40.	Mudstone, greenish gray (5 GY 6/1), sandy, numerous calcareous glaebules	6.0 (1.8)
*39.	Sandstone, yellowish gray (5 Y 7/2), fine to coarse grained, angular to subangular grains, poorly sorted, micaceous, calcareous, cross-bedded; coarsens upward; moderate reddish brown (10 R 4/6), ironstone concretions; channeled into lower units; rare lower vertebrates (UCM Loc. 80087)	4.0 (1.2)
38.	Mudstone, greenish gray (5 GY 7/1), sandy; calcareous glaebules.	2.5 (0.8)

37.	Mudstone, pale olive (10 Y 5/2), sandy.	2.0 (0.6)
36.	Mudstone, pale red-greenish gray, mottled	1.0 (0.3)
35.	Mudstone, light olive gray (5 Y 7/1), sandy; calcareous glaebules.	5.0 (1.5)
34.	Sandstone, yellowish gray (5 Y 8/1), very fine grained, friable, calcareous.	6.0 (1.8)
33.	Mudstone, red-brown-yellow, mottled, sandy. . . .	1.0 (0.3)
32.	Sandstone, dusky yellow (5 Y 6/4), fine to medium grained rock fragments, angular to subangular grains, bioturbated, some pedotubules . .	10.0 (3.0)
31.	Mudstone, dusky yellow-green (5 GY 4/2), sandy; coarse angular sand grains, very little silt, predominantly clay.	5.0 (1.5)
30.	Sandstone, light olive gray (5 Y 6/1), coarse to fine grained, subangular to rounded rock fragments, poorly sorted, crossbedded, calcareous; resistant ridge forming; reddish brown (10 R 4/6)-yellow mottled at base	6.0 (1.8)

Wind River Formation, Lower Gray Member:

Lower Gray Sequence:

29.	Mudstone, purplish red.	2.0 (0.6)
28.	Mudstone, green; calcareous glaebules	4.0 (1.2)
27.	Mudstone, red-green mottled; calcareous glaebules .	4.0 (1.2)
26.	Mudstone, green	3.0 (0.6)
25.	Sandstone, yellowish gray	4.0 (1.2)
24.	Mudstone, light gray.	4.0 (1.2)
23.	Mudstone, medium gray	1.0 (0.3)
22.	Mudstone, gray; light brown mottling, gypsum crystals.	3.0 (0.9)
21.	Sandstone, greenish gray (5 GY 6/1) with yellowish brown (10 YR 6/4) streaks; very fine grained; calcareous.	2.5 (0.8)

20.	Sandstone, dusky yellow (5 Y 6/4), fine grained, well sorted, subangular rock fragments, micaceous; intraformational claystone clasts at base.	2.5 (0.8)
19.	Mudstone, greenish gray with yellow streaking; carbonaceous; bioturbated; numerous gypsum crystals; fossil wood encrusted with gypsum . . .	3.5 (1.1)
18.	Mudstone, pale olive (10 Y 6/2), sandy; numerous gypsum crystals.	4.0 (1.2)
*17.	Mudstone, grayish yellow green (5 GY 7/2), silty, fissile, some gypsum crystals; fossil wood and small bone fragments (no locality number)	2.0 (0.6)
*16.	Mudstone, grayish yellow green, calcareous glaebules, turtle shell fragments (no locality number)	3.0 (0.9)
15.	Claystone, medium gray, laminated; excellent marker bed; well preserved seed impressions locally	1.0 (0.3)
*14.	Claystone, grayish yellow green (5 GY 7/2), calcareous pedotubules and glaebules; coprolites; eggshells; partially articulated skeletal material of <u>Allognathosuchus</u> and <u>Crocodylus</u>, associated limbs of <u>Coryphodon</u> sp., microvertebrates and turtles common in spots (UCM Loc. 79039)	3.0 (0.9)
*13.	Mudstone, yellowish gray (5 Y 8/1), silty	4.0 (1.2)
12.	Mudstone, light gray-light greenish yellow mottled, sandy; calcareous glaebules, some pebbles	2.0 (0.6)
*11.	Sandstone, yellowish gray (5 Y 8/1), laminated bedding, calcareous; rip up clasts at base; black bone fragments; sharp lower contact	3.0 (0.9)
*10.	Claystone, greenish gray (5 GY 7/1), black bone fragments	0.5 (0.2)
9.	Mudstone, yellowish gray (5 Y 7/1), some very fine sand, carbon streaked in part; high clay content	2.0 (0.6)

*8.	Sandstone, light gray, fine to coarse grained; some interbedded conglomerates with Mesozoic clasts (sandstones, conglomerates, porcelainite and limestone), vertebrate fossils at top of unit (UCM 79045).	31.0 (9.5)
7.	Vegetation covered.	15.0 (4.6)
6.	Conglomerate, pale olive (10 Y 6/2), intraformational, micaceous, angular, fine to medium grained quartz sand matrix, muddy laminated bedding, laterally becomes fine grained sandstone, dusky yellow (10 Y 6/2) and greenish gray (5 GY 6/1) claystone clasts at base, channeled into lower unit.	4.0 (1.2)
5.	Mudstone, yellowish gray (5 Y 7/2), sandy, sharp lower contact	2.0 (0.6)
4.	Sandstone, yellowish gray (5 Y 9/1), very fine to coarse grained, well rounded to angular grains, muddy; interbedded conglomerates composed of well rounded Mesozoic rock fragments, matrix of conglomerates primarily well rounded and well sorted quartz grains.	8.0 (2.4)
3.	Mudstone, moderate red (5 R 4/6)-pinkish red (5 YR 5/1) mottled, sandy, bioturbated, non-preferentially cemented burrows; laterally contacts Mowry Shale where large angular blocks of porcelainite are incorporated into unit. . . .	2.0 (0.6)
2.	Mudstone, gray.	0.5 (0.2)
1.	Sandstone, gray; unconformable on Mowry Shale . .	6.0 (1.8)

Measured Section 2. West of Red Creek. Partial section of Wind River Formation. Sec. 7, T. 38 N., R. 87 W.

Wind River Formation:

9.	Sandstone, yellowish gray (5 Y 7/2), fine grained, poorly sorted, calcareous, occasional red mottling and glaebules	10.0 (3.0)
8.	Mudstone, greenish gray (5 GY 6/1), silty, calcareous; grades upward into red-green and green-purple mottled mudstone.	9.0 (2.7)
7.	Mudstone, pale red (10 R 6/2), some sand and silt, calcareous; some mottling.	7.0 (2.1)
6.	Sandstone, mottled green-red, fine grained; some calcareous glaebules	3.0 (0.9)
5.	Mudstone, grayish yellow (5 GY 6/2); some sandy lentiles with angular to subangular coarse quartz grains; some calcareous glaebules.	25.0 (7.6)
4.	Sandstone, mottled green-red, very fine to fine grained; red mottles increase at top; calcareous glaebules at top	2.0 (0.6)
3.	Sandstone, light greenish gray (5 GY 8/1), very fine grained, calcareous; highly calcareous glaebules.	8.0 (2.4)
2.	Conglomerate, greenish gray, cobble clasts primarily derived from Mesozoic; matrix is fine to coarse grained sand	5.0 (1.5)
1.	Mudstone, reddish brown (10 R 5/6) and gray (5 GY 6/1) mottled; noncalcareous glaebules, sharp lower contact.	12.0 (3.6)

Unconformity
Chugwater group

Rainbow Butte Stratigraphic Section

Measured Section 3. Rainbow Butte stratigraphic section. Partial section of the Lost Cabin Member of the Wind River Formation. Rainbow Butte, Hill 6335, Sec. 19, T. 38 N., R. 87 W.; dip 6 degrees South, strike N. mag 82 degrees W., 25 June, 1980.

Quaternary:

25. Gravel, poorly sorted, clast supported, cobble. . 2.0 (0.6)

Wind River Formation, Lost Cabin Member:

Variegated Sequence:

24. Mudstone, red-green mottled; highly weathered . . 2.2 (0.7)

23. Mudstone, green, calcareous; highly weathered . . 1.0 (0.3)

22. Mudstone, red-green mottled; highly weathered . . 6.5 (2.0)

21. Sandstone, gray (5 GY 7/1), fine to medium grained, micaceous, muddy, friable; preferentially cemented zones 9.0 (2.7)

20. Mudstone, gray (lower part) to mottled red-gray (upper part), silty; calcareous glaebules and vertically oriented pedotubules; sharp undulatory lower contact. 2.0 (0.6)

19. Mudstone, mottled red-gray (5 GY 6/1), silty; calcareous glaebules. 3.5 (1.1)

18. Mudstone, gray (5 GY 6/1), calcareous, sandy. . . 4.0 (1.2)

*17. Mudstone, grayish yellow green (5 GY 7/2), sandy; contains rounded intraformational claystone pebbles at base (UCM Loc. 80065-17) 3.5 (1.1)

16. Mudstone, yellowish green (5 GY 6/2), micaceous, sandy 3.0 (0.9)

*15. Sandstone, greenish gray, fine grained, micaceous, muddy (UCM Loc. 80065-15). 2.5 (0.8)

*14.	Sandstone, greenish gray, fine grained; intraformational mudstone clasts; calcareous glaebules formed in two layers, one at base and one 1.0 ft. (0.3 m) above base; fossils restricted to glaebule horizons (UCM Loc. 80065-14).	4.5 (1.4)
13.	Mudstone, grayish yellow green (5 GY 6/2), silty; calcareous glaebules and noncalcareous pedotubules	1.5 (0.5)
12.	Sandstone, greenish gray (5 GY 6/1), fine grained, calcareous; glaebules oriented in horizontal plane.	6.0 (1.8)
*11.	Mudstone, gray; spheroidal calcareous glaebules and calcareous pedotubules (UCM Loc. 80065-11). .	2.0 (0.6)
*10.	Mudstone, mottled red-green, calcareous; color mottles shift from green-red at bottom to red-gray to orange-gray at top; calcareous glaebules at top and base of unit (UCM Loc. 80065-10) . . .	2.5 (0.8)
9.	Sandstone, yellow-green (5 GY 6/2), subangular fine to very coarse grained, poorly sorted, slightly calcareous; calcareous glaebules	2.5 (0.8)
*8.	Mudstone, mottled brick red-pale yellowish green (5 GY 6/1), sandy, bioturbated; calcareous glaebules; green mottles occur in thin non-preferentially cemented pedotubules (UCM Loc. 80065-8).	2.0 (0.6)
7.	Mudstone, greenish gray, micaceous, silty; glaebules; mica decreases in grain size from bottom to top from coarse to fine; sharp lower contact .	5.5 (1.7)
*6.	Sandstone, greenish gray, medium to coarse grained, poorly sorted, calcareous; subrounded pebble conglomerate at base, well rounded bone fragments; top forms resistant ledge (UCM Loc. 80065-6).	3.0 (0.9)
*5.	Mudstone, brick red below to mottled red-green above, calcareous, bioturbated; yellowish brown glaebules and pedotubules (UCM Loc. 80065-5). . .	3.0 (0.9)
*4.	Claystone, greenish gray-light brownish gray (5 YR 6/1) mottled, micaceous; non-preferentially cemented pedotubules (UCM Loc. 80065-4)	5.0 (1.5)
3.	Mudstone, grayish green (10 GY 5/2), micaceous, silty, bioturbated; noncalcareous pedotubules . .	2.5 (0.8)

*2. Mudstone, green-yellow-red mottled, silty, bioturbated (UCM Loc. 80065-2) 3.0 (0.9)

*1. Mudstone, grayish green (10 GY 5/2), silty; calcareous chocolate brown to orange-brown pedotubules oriented perpendicular to bedding plane; glaebule concentration (25-40% total volume) at top of bed; conglomeratic lense at 3.0 ft. (0.9 m) above base of unit, clasts up to 1.0 cm in diameter (UCM Loc. 80065-1); basal contact not exposed 5.0 (1.5)

Davis Ranch Stratigraphic Sections

Measured Section 1979. Davis Ranch (Sullivan Ranch Locality or Guthrie's (1971) Locality 1). Partial section of Wind River Formation, Lost Cabin Member. Sec. 6, T. 37 N., R. 87 W.

<u>Wind River Formation, Lost Cabin Member</u>:

12.	Mudstone, gray and sandstone, gray.	10.0+ (3.0)
11.	Sandstone, tan to light brown, fine to very fine grained, calcareous, biotite flakes present . . .	26.9 (8.2)
*10.	Mudstone, bluish gray, sandy, calcareous; pedotubules and glaebules (UCM Loc. 79041).	44.7 (13.6)
*9.	Sandstone, buff to tan, calcareous, fine to medium, subangular, arkosic (no Locality number). . .	7.7 (2.3)
8.	Ash, off-white, calcareous, resistant	2.3 (0.7)
*7.	Mudstone, gray, some medium to fine sand (no Locality number).	12.8 (3.9)
6.	Mudstone, yellowish gray, noncalcareous, occasional calcareous sandstone lenses, micaceous, fine grained, occasional glaebules	7.0 (2.1)
*5.	Mudstone, gray, sandy (UCM Loc. 79043).	12.8 (3.9)
*4.	Mudstone, mottled red, grades laterally into Unit 5 (UCM Loc. 79043).	3.7 (1.1)
3.	Mudstone, purple.	2.3 (0.7)
*2.	Mudstone, mottled red, micaceous, calcareous (UCM Loc. 79042)	10.5 (3.2)
1.	Mudstone, mottled red-gray, glaebules	4.0 (1.2)

Measured Section 8. West Davis Ranch. Partial section of Lost Cabin Member of Wind River Formation. Center Sec. 36, T. 38 N., R. 88 W.

Wind River Formation, Lost Cabin Member:

15.	Sandstone, gray, crossbedded.	25.0+ (7.6)
14.	Mudstone, gray.	12.0 (3.6)
13.	Mudstone, red, predominantly clay with some silt, calcareous, not laterally persistent (equivalent to Measured Section 1979, Unit 2 to Unit 4, UCM Loc. 79042)	21.5 (6.6)
12.	Mudstone, green, calcareous glaebules at base . .	17.0 (5.8)
*11.	Mudstone, mottled red-gray, calcareous, tabular (UCM Loc. 81021).	1.5 (0.5)
*10.	Mudstone, green, micaceous; turtle shell fragments 3.0 ft. (0.9 m) above base; lenticular (UCM Loc. 81020).	12.5 (3.8)
9.	Mudstone, gray, calcareous.	11.5 (3.5)
8.	Mudstone, purple with white top; tabular, excellent marker bed	4.0 (1.2)
7.	Mudstone, alternating red and gray silt and very fine sand layers, calcareous, micaceous. . .	6.0 (1.8)
6.	Sandstone, green, subrounded to angular medium grained, well sorted, calcareous; quartz arenite, some biotite and feldspar; preferentially cemented.	2.0 (0.6)
*5.	Mudstone, mottled purple-green; tabular, calcareous glaebules and pedotubules; associated partial skeletons of primate and crocodile fossil vertebrates abundant (UCM Loc. 81019).	3.5 (1.1)
*4.	Mudstone, mottled dark gray-light gray, calcareous; some quartz and biotite grains; calcareous lense-shaped glaebules and pedotubules; laterally grades to sandstone; associated skeletal remains of ?varanid and <u>Palaeosyops</u> (UCM Loc. 81018).	10.5 (3.2)

3. Mudstone, mottled gray-red, calcareous; alternating mottled red and gray horizons with distinct lower contacts; laterally grades into sandstone where red coloration is less apparent . 3.0 (0.9)

*2. Mudstone, red, tabular; biotite at base; some pedotubules; grades laterally into sandstone (UCM Loc. 81017). 1.5 (0.5)

1. Mudstone, mottled brown-yellow-green, silty with some subangular sand and biotite; laminated in part; iron oxide nodules; carbonaceous in part; sharp upper contact 6.5 (2.0)

Measured Section 9. Davis Ranch. Partial section of Lost Cabin Member of Wind River Formation. NW ¼ NW ¼ Sec. 6, T. 37 N., R. 87 W.

Wind River Formation, Lost Cabin Member:

10.	Conglomerate, pale yellow-brown (10 YR 6/2), intraformational; calcareous at base; matrix with alternating claystone and silty mudstone laminations	2.5 (0.8)
9.	Mudstone, mottled gray-red, sandy, slightly calcareous	3.5 (1.1)
*8.	Mudstone, red, calcareous glaebules; laterally grades into apron-channel sandstone (UCM Loc. 79043).	2.5 (0.8)
7.	Mudstone, mottled; color changes from mottled yellow-red at base to mottled red-green to mottled green-red at top; calcareous glaebules at base	10.0 (3.0)
*6.	Mudstone, dark reddish brown (10 R 3/4), micaceous, silty; abundant calcareous glaebules and pedotubules; some carbonaceous material; abundant fossil vertebrates, including some articulated remains; bone in situ surrounded by layer of green colored mudstone approximately 2 to 5 mm thick (UCM Loc. 79042).	14.0 (4.3)
*5.	Claystone, mottled red-green, vertebrate fossils at top of unit (UCM Loc. 81025)	2.5 (0.8)
4.	Mudstone, mottled red to red-gray; red mudstone is noncalcareous whereas gray mudstone is calcareous; glaebules at top of unit (UCM Loc. 81024).	4.0 (1.2)
*3.	Mudstone, gray, laterally changing to mottled gray-red; fossils weathering out at 3 ft. (0.9 m) and 7 ft. (2.1 m) above base; ?creodont skull and jaws (CM collections) (UCM Loc. 81023).	7.0 (2.1)
2.	Sandstone, gray, fine grained, tabular, laminated bedding	0.5 (0.2)
*1B.	Mudstone, gray, calcareous; mottled red horizons at 3 and 4.5 ft. above base of unit; fossils at 4.0 ft. (1.2 m) above base and at base of unit; sharp contact with lower unit (UCM Loc. 81022, Anthill collection)	6.5 (2.0)

*1A.	Mudstone, gray, calcareous glaebules at 1.5 ft. (0.4 m) above base; fossils at 2.0 ft. (0.6 m) above base (UCM Loc. 80101)	3.0 (0.9)

Section 10. Davis Ranch. Partial section of Lost Cabin Member of the Wind River Formation. Measured in NW ¼ NW ¼ Sec. 6, T. 37 N., R. 87 W.

Wind River Formation, Lost Cabin Member:

14.	Mudstones and sandstones, alternating	10.0+ (3.0)
13.	Sandstone, gray, conglomeratic at base; apron-channel geometry; conglomerate contains intraformational glaebules and probable Pre-cambrian clasts, calcareous canonball concretions	17.5 (5.3)
*12.	Mudstones and sandstones, alternating; fossil fragments 1 ft. (0.3 m) above base (no Locality number)	24.0 (7.3)
*11.	Mudstone, gray, contains numerous calcareous glaebules and pedotubules, well preserved mammalian fossils (UCM Loc. 79041)	4.0 (1.2)
*10.	Sandstones and mudstones, alternating; fossil fragments at 2.0 ft. (0.6 m) above base (no Locality number).	30.0 (9.2)
9.	Ash, weathers white, resistant, laterally extensive, good horizon marker.	2.0 (0.6)
*8.	Sandstone, greenish gray, medium to coarse grained, multistoried, apron-channel geometry; highly calcareous glaebules at top, some gypsum crystals (UCM Loc. 81027, Anthill collection).	19.5 (5.9)
*7B.	Mudstone, gray, resistant; forms low rounded knolls; associated skeletal elements of single individuals (UCM Loc. 81026).	4.5 (1.4)
7A.	Sandstone, greenish gray, channeled	1.0 (0.3)
*6.	Mudstone, alternating red and gray tabular units, some red-gray mottling, silty and sandy; calcareous glaebules, associated skeletal elements of single individuals; laterally equivalent to apron-channel sandstone which cuts into lower unit (UCM Loc. 81043).	4.5 (1.4)
5.	Sandstone, gray, fine grained, predominantly quartz, calcareous; red mottled at top.	3.5 (1.0)

4. Mudstone, mottled red-grayish green; lower 2.0 ft. (0.6 m) mottled purple-green; middle 1.0 ft. (0.3 m) mottled brown-yellow with iron oxide glaebules; upper 2.5 ft. (0.8 m) mottled green-red (same bed as Measured Section 9, Unit 7). . . 5.5 (1.7)

3. Mudstone, brick-red, calcareous; greenish gray calcareous glaebules and pedotubules common in upper part, fossiliferous throughout (UCM Loc. 79042) 12.5 (3.8)

2. Mudstone, mottled red-gray. 5.0 (1.5)

*1. Mudstone, gray, silty; upper 3.0 ft. (0.9 m) contains more sand; fossils and calcareous glaebules in lower 4.0 ft. (1.2 m) (UCM Loc. 81023) 7.0 (2.1)

Measured Section 11. Davis Ranch East. Partial section of Wind River Formation. NW ¼ NE ¼ Sec. 6, T. 37 N., R. 87 W.

Wind River Formation, Lost Cabin Member:

12.	Claystone, dark gray.	2.0 (0.6)
*11.	Mudstone, gray, turtle shell fragments (no Locality number)	3.0 (0.9)
10.	Claystone, gray, fissile; sharp lower contact . .	1.0 (0.3)
*9.	Sandstone, greenish gray, medium to coarse grained, micaceous; sharp lower contact; turtle shell and crocodile fragments (no Locality number; correlates with Measured Section 12, Unit 4)	1.0 (0.3)
8.	Claystone, dark gray, calcareous, fissile; upper 4.0 ft. (1.2 m) silty mudstone.	6.0 (1.8)
7.	Mudstone, dark gray	2.5 (0.8)
6.	Mudstone, light yellowish brown, calcareous, sandy; forms semi-resistant ridge; sharp lower contact	1.0 (0.3)
5.	Mudstone, dark gray, sandy.	4.5 (1.4)
4.	Mudstone, light yellowish brown, sandy.	3.0 (0.9)
*3.	Mudstone, gray, silty, intraformational claystone pebbles at base, sharp lower contact; mammalian skeletal fragments (no Locality number)	9.5 (2.9)
2.	Sandstone, yellowish brown, medium grained, predominantly quartz sand, calcareous; calcareous pedotubules in upper part; grades upward into mudstone.	6.5 (2.0)
*1.	Mudstone, gray, sandy; non-calcareous at base becoming more calcareous toward top; calcareous glaebules at 5 ft. (1.5 m) above base with dark brown interior (UCM Loc. 81028)	11.5 (3.5)

Measured Section 12. Davis Ranch East. Partial section of Lost Cabin Member of Wind River Formation. SE ¼ NE ¼ NE ¼ Sec. 6, T. 37 N., R. 87 W.

Wind River Formation, Lost Cabin Member:

10.	Mudstone, gray.	10.5 (3.2)
9.	Sandstone, gray, medium to coarse grained, poorly sorted, calcareous, apparent gradational contact with upper unit	1.0 (0.3)
8.	Mudstone, gray.	9.5 (2.9)
*7.	Mudstone, red, lower part calcareous glaebules and pedotubules, upper part orange-red-yellow-green mottling; highly weathered (UCM Loc. 80100, unit equivalent to Measured Section 9, Units 6 and 7).	14.0 (4.2)
6.	Mudstone, gray, highly weathered (equivalent to Measured Section 9, Units 1 to 5)	21.0 (6.3)
*5.	Mudstone and sandstone, gray; unit shifts from sandstone at base to mudstone to claystone to mudstone at top; calcareous glaebules and turtle shell and crocodile fragments (no Locality number)	7.0 (2.1)
4.	Sandstone, grayish green, medium to coarse grained, micaceous, calcareous (correlates with Measured Section 11, Unit 9).	0.5 (0.2)
3.	Mudstone, gray, silty	1.5 (0.5)
2.	Sandstone, light yellowish brown, fine to medium grained, noncalcareous.	3.0 (0.9)
*1.	Mudstone, gray, silty	7.0 (2.1)

Buck Spring Stratigraphic Section

Measured Section 13. Buck Spring stratigraphic section, probable type area of the Lost Cabin Member of the Wind River Formation. Partial section of Lost Cabin Member measured in SW ¼ Sec. 15, T. 38 N., R. 89 W. Beds nearly horizontal, slight dip to south.

Wind River Formation, Lost Cabin Member:

17.	Sandstone, yellowish brown, apron-channel geometry.	10.0 (3.0)
16.	Mudstone, greenish gray	9.0 (2.7)
15.	Mudstone, mottled red-gray.	5.0 (1.5)
14.	Mudstone, greenish gray	9.0 (2.7)
*13.	Mudstone, mottled red-green; calcareous glaebules and pedotubules; mottling occurs as thin striae (?rhizoliths); associated skeletal elements of mammal individuals (UCM Loc. 81033)	5.0 (1.5)
12.	Mudstone, greenish gray	4.5 (1.4)
*11.	Mudstone, alternating grayish red (5 R 4/2) and greenish gray (5 G 7/1) bands, thinly laminated, silty, very little sand; color bands vary from several centimeters to approximately .3 m thick; numerous calcareous glaebules, some calcareous pedotubules; some articulated skeletal remains of mammals (UCM Loc. 81032)	10.5 (3.2)
*10.	Mudstone, same lithology as Unit 11, with well-defined red horizon at top (UCM Loc. 81031) . . .	4.0 (1.2)
*9.	Sandstone, green, fine to very coarse grained, calcareous; apron-channel geometry; abraided and unabraided bone fragments (UCM Loc. 81030). .	3.0 (0.9)
*8.	Mudstone, grayish red (10 R 4/2) with very pale green, anastomizing striae (10 G 8/3) (?rhizoliths); fossils extremely abundant; calcareous glaebules at base. Same unit as Granger's (1910) dark red stratum and Unit 2, Measured Section 9 of Tourtelot (in Keefer, 1965a) (UCM Loc. 81029).	12.0 (3.6)

7.	Sandstone, yellow-brown, fine to medium grained; grades from well sorted medium grained sandstone at base to poorly sorted mudstone at top	8.5 (2.6)
6.	Mudstone, gray.	6.5 (2.0)
5.	Sandstone, gray, fine to medium grained, poorly sorted, micaceous, crossbedded.	3.5 (1.0)
4.	Mudstone, purple mottled, calcareous glaebules throughout, septarian concretions	3.0 (0.9)
*3.	Sandstone and mudstone, yellow-brown; calcareous pedotubules; turtle and crocodilian fragments at top (no Locality number).	9.0 (2.7)
2.	Mudstone, gray, silty	4.5 (1.3)
1.	Sandstone, yellowish green, micaceous; preferentially cemented	6.5 (2.0)

Deadman Butte Stratigraphic Sections

Measured Section 16. Deadman Butte Area. Partial section of Wind River Formation. NE ¼ NE ¼ NE ¼ Sec. 33, T. 38 N., R. 87 W.

Wind River Formation:

4.	Sandstone, yellow-brown, medium grained, calcareous; dark brown iron oxide stain at base	1.0+ (0.3)
*3.	Shale, carbonaceous, very dark brown, turtle shell fragments (no Locality number)	4.0 (1.2)
2.	Mudstone, gray with yellow-orange mottling; silty.	11.0 (3.3)
1B.	Vegetation cover, poorly exposed	30.0 (9.1)
1A.	Mudstone, light gray, sandy; black bone fragments (no Locality number)	10.0 (3.0)

Measured Section 17. Palaeosyops jaw locality, Deadman Butte Area. Partial section of Lost Cabin Member of Wind River Formation. SW ¼ SW ¼ SW ¼ Sec. 27, T. 38 N., R. 87 W.

Wind River Formation, Lost Cabin Member:

Upper Gray Sequence (?):

5.	Mudstone, gray	9.0 (2.7)
4.	Sandstone, dusky yellow (5 Y 6/4) with dark yellowish orange striae (10 YR 6/6); fine grained, well sorted, tabular	2.0 (0.6)
*3.	Mudstone, grayish olive (10 Y 4/2), silty; upper part predominantly clay; calcareous glaebules at 1.0 ft. (0.3 m) above base (UCM Loc. 81011). . . .	14.0 (4.2)
2.	Sandstone, dusky yellow (10 Y 6/4) to pale olive (5 Y 6/2); very fine grained, calcareous	3.5 (1.1)
1.	Mudstone, light grayish green (5 G 7/1), silty, some fine sand; small calcareous pellet-shaped glaebules; calcareous rhizoliths and intraformational burrows; popcorn weathering, weathers bluish gray in outcrop; associated Palaeosyops borealis skeletal elements, abundant mammal fossils; calcified wood fragments and carbonized and noncarbonized plant impressions (UCM Loc. 81010)	16.5 (5.0)

Measured Section 17a. Palaeosyops jaw locality, Deadman Butte Area. Partial Section of Lost Cabin Member of Wind River Formation. SW ¼ SW ¼ SW ¼ Sec. 27, T. 38 N., R. 87 W.

Wind River Formation, Lost Cabin Member:

9.	Mudstone, gray, silty; silt increases in unit up to 15 ft. (4.5 m) above base; at 15.0 ft. (4.5 m) sediments are dark gray claystone as in Unit 5. .	24.0 (7.2)
8.	Sandstone, yellowish gray to dusky yellow, fine grained, calcareous; semi-resistant; upper part contains more medium to coarse sand grains and is micaceous.	2.0 (0.6)
*7.	Mudstone, gray, calcareous; invertebrate and vertebrate fossil fragments at 2.0 ft. (0.6 m) above base (UCM Loc. 81011).	22.0 (6.6)
6.	Sandstone, pale olive (10 Y 6/2), fine grained, calcareous, vertically weathering.	3.0 (0.9)
5.	Claystone, gray.	1.0 (0.3)
4.	Mudstone, gray, silty; calcareous glaebules. . . .	4.0 (1.2)
3.	Sandstone, gray, crossbedded	3.5 (1.0)
*2.	Mudstone, gray, bluish cast from distance, calcareous glaebules (UCM Loc. 81010)	20.5 (6.2)
1.	Sandstone, light olive gray (5 Y 5/2), fine to medium grained, angular to subangular quartz grains	4.0 (1.2)

Measured Sections 18 and 19. Deadman Butte Area. Partial section of Lower Gray and Lost Cabin Members of Wind River Formation. W ½ Sec. 22, T. 38 N., R. 87 W. Dip to 10 degrees South, N. mag 60 degrees East, 22 June, 1981.

Wind River Formation, Lost Cabin Member:

Variegated Sequence:

19.	Sandstone, light yellowish gray, medium to coarse subangular quartz, feldspar and lithic fragments, calcareous, crossbedded; iron oxide concretions; apron-channel geometry; channeled into underlying units	30.0 (9.0)
*18.	Claystone, dark bluish gray; associated skeletal elements of Coryphodon and crocodile (UCM Loc. 80090).	2.0 (0.6)
17.	Shale, carbonaceous, dark gray.	1.0 (0.3)
16.	Mudstone, mottled red-gray, calcareous (UCM Loc. 80088).	8.0 (2.4)
15.	Sandstone, light olive to white, fine grained, calcareous; orange mottles at top of unit; calcareous glaebules and pedotubules	5.0 (1.5)
14.	Sandstone, mottled red-yellow-gray, fine grained, poorly sorted; gypsum crystals litter surface; weathers brick red.	9.0 (2.7)

Wind River Formation, Lower Gray Member:

Lower Gray Sequence:

13.	Mudstone, alternating yellowish gray and gray bands; gypsum crystals litter surface	35.0 (10.7)
12.	Mudstone, dark gray	0.5 (0.2)
11.	Sandstone, light olive green, medium grained, quartz arenite.	1.0 (0.3)
10.	Mudstone, dark gray	1.5 (0.5)

*9.	Sandstone, yellowish gray, very fine to fine, well rounded to subrounded quartz grains, calcareous, poorly sorted; calcareous glaebules and pedotubules; fossiliferous at top of unit (UCM Loc. 80089, probable correlate of UCM Loc. 80062).	3.5 (1.1)
8.	Mudstone, greenish gray, sandy.	3.0 (0.9)
7.	Sandstone, light olive, very fine to fine grained; some pebble conglomerate lenses	3.5 (1.1)
6.	Mudstone, dark olive gray, silty.	6.5 (2.0)
Offset		
5.	Sandstone, grayish yellow green (5 GY 7/2), very fine to fine rounded quartz grains; preferentially cemented; lenticular conglomerates with chert and porcelainite pebble clasts; calcareous rhizoliths, reticulate glaebule-pedotubule masses; pedotubules in vertical position and in horizontal zones.	25.0 (7.6)
4.	Claystone, olive gray (5 Y 4/1); intraformational mudstone clasts from Unit 3 at base	1.0 (0.3)
3.	Mudstone, greenish gray to pale olive, silty, micaceous; sharp lower contact.	6.5 (2.0)
2.	Mudstone, pale olive, some quartz sand grains which are all well rounded.	2.5 (0.8)
1B.	Mudstone, yellowish gray to pale olive, sandy, micaceous; sand decreases toward top of bed, fossil vertebrates in lower 3.0 ft. (0.9 m) (UCM Loc. 81009)	19.0 (5.7)
*1A.	Sandstone, gray, poorly sorted; calcareous rhizoliths, pedotubules and glaebules in upper part; conglomeratic lenses of chert and porcelainite with some mammal bone fragments; numerous isolated bone and teeth fragments (UCM Loc. 81008) .	5.0+ (1.5)

Measured Section 20. Deadman Butte Area. Partial section of Lost Cabin and Lower Gray Members of the Wind River Formation, E. ½ Sec. 22, T. 38 N., R. 87 W.

<u>Wind River Formation, Lost Cabin Member:</u>

Variegated Sequence:

11.	Sandstone, yellow-brown; highly weathered (equivalent to Measured Sections 18 and 19, Unit 19).	10.0+ (3.0)
10.	Mudstone, red, highly weathered	1.0 (0.3)
9.	Sandstone, yellow-brown, highly weathered	4.0 (1.2)
8.	Mudstone, red, highly weathered	3.5 (1.1)
7.	Sandstone, light gray, highly weathered	3.5 (1.1)
6.	Mudstone, light brown, sandy; gypsum crystals litter surface.	4.0 (1.2)
5.	Shale, carbonaceous	3.0 (0.9)

<u>Wind River Formation, Lower Gray Member:</u>

Lower Gray Sequence:

4.	Mudstone, dark gray to yellowish brown, gypsum crystals litter surface	10.0 (3.0)
3.	Mudstone, light gray.	12.5 (3.8)
*2.	Mudstone, yellowish olive, some quartz sand grains; numerous fossil vertebrates randomly distributed within unit; fossiliferous at 5 to 15 ft. (1.5 to 4.6 m); laterally shifts to sandstone with conglomeratic lenses of Mesozoic clasts (UCM Loc. 80062).	21.5 (6.5)
*1.	Conglomerate, clay ball, carbonaceous, dark gray to black; thinly laminated; gypsum crystals, turtle shell fragments somewhat abundant.	1.0 (0.3)

Measured Section 21. West of Rainbow Butte and Red Creek. Partial section of Wind River Formation, SW ¼ Sec. 22, T. 38 N., R. 88 W.

Wind River Formation:

9.	Sandstones and conglomerates, yellowish green, crossbedded; channeled into lower units; Precambrian and Flathead clasts in conglomerates . .	9.0 (2.7)
*8.	Mudstones, gray, sandy, calcareous, calcareous glaebules and vertical pedotubules, small bone fragments (UCM Loc. 81040)	20.0 (6.1)
7.	Sandstone and sandy mudstones, gray to yellow-brown, alternating, matrix supported conglomerate with probable Paleozoic and Precambrian cobbles; lower contact iron stained	21.0 (6.4)
6.	Mudstone, gray; calcareous glaebules.	1.0 (3.0)
5.	Sandstone, reddish brown, matrix supported conglomerate at top with dolomite, limestone and sandstone clasts of probable Paleozoic origin and Precambrian clasts, channeled into lower unit.	16.0 (4.9)
4.	Mudstone, greenish gray; calcareous glaebules; unit purple mottled at top.	7.0 (2.1)
3.	Sandstone, yellowish gray, multistoried, small scale crossbedding; pebble conglomerate lenses; conglomerate clasts derived from Paleozoic and Precambrian strata; becomes coarser at top. . . .	13.0 (3.9)
2.	Mudstone, gray.	8.0 (2.4)
1.	Carbonaceous shale, chocolate brown	2.0 (0.6)

Appendix B. Description of Fossiliferous Horizons.

Each fossiliferous horizon from which mammalian fossils were recovered is listed in numerical order according to the UCM locality number. The location of a fossiliferous horizon is given as the measured section (MS) number, unit (U) position within that measured section, and legal location. The position of a fossiliferous horizon within a measured section is shown on Plate II, and its areal location is shown on Plate I. Plates III and IV give a list of the number of specimens of each mammalian taxon recovered from the horizon. Appendix A gives more detailed lithological information for each fossiliferous horizon in a measured section.

UCM Loc. 79039: "Unit 13" Blue Croc Bed

Location: MS-1, U-14; Sec. 17-20, T. 38 N., R. 87 W.

Horizon Description: Bioturbated, gray claystone with calcareous glaebules and pedotubules.

Material Preserved: Articulated and scattered skeletal elements of single individuals, turtle shell fragments, isolated teeth, coprolites, burrows.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect, excavation.

Comments: Locality is exposed for one km. In several places associated bones of single crocodile and Coryphodon individuals can be found, some in part articulated. Some elements show concoidal depressions suggestive of carnivore activity. In situ bones are black with no mineralogical surface coating. Crocodiles and turtles are most abundant.

UCM Loc. 79040: Someday locality

Location: MS-1, U-61; SE ¼, Sec. 19, T. 38 N., R. 87 W.

Horizon Description: Bioturbated, mottled red-gray mudstone, with calcareous glaebules and pedotubules occurring at specific horizons; intraformational burrows and some rhizoliths present.

Material Preserved: Disarticulated and scattered partial skeletons of Hyrachyus, numerous isolated turtle and crocodile elements, one complete shell of trionychid, isolated limb elements and teeth of mammals and lower vertebrates common, eggshells, some coprolites with gar scales and lizard scutes, small meniscate burrows, rare silicified plant materials.

Paleoenvironment: Overbank/paleosol; abundant aquatic and semi-aquatic vertebrate materials suggest near permanent body of water.

Methods: Surface prospect, screen wash, excavation.

Comments: Taphonomic data collected during excavation indicate random orientation for long bones. Many bone fragments are vertical. Burrows are filled with intraformational sediment and oriented vertically as are many rhizoliths. In situ bones are black in color with no mineralogical surface coating. Elements are exceptionally well preserved and some show concoidal depressions indicating carnivore activity. Crocodiles and turtles are extremely common. Isolated teeth are the most common mammalian element.

UCM Loc. 79041: Sullivan Ranch Unit 10, AMNH Davis Ranch locality, in part

Location: MS-1979, U-10; top of hill 6164, NW ¼, Sec. 6, T. 37 N., R. 87 W.

Horizon Description: Gray mudstone with calcareous glaebules and pedotubules.

Material Preserved: Primarily mammalian remains. Some associated skeletal elements of single individuals (snake, large and small mammal). Knightomys partial skeleton, including partial skull and both lower jaws with articulated vertebrae and hind limb elements. Few turtle or crocodile remains.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect.

Comments: Jaw materials of mammals are very well preserved. The bone is white with chocolate brown colored teeth. Bones may have a calcareous glaebule covering. Very few isolated teeth are found. Associated skeleton of Knightomys may be from a coprolite, owl pellet or mummified carcass. Some materials in AMNH from "Davis Ranch" come from this fossiliferous horizon and can be distinguished from other fossils at this locality by their preservation.

UCM Loc. 79042: UCM Sullivan Ranch Bed 2, AMNH Davis Ranch locality, PU 5 mi. N and E of Arminto, CM 8-15' red bed, Guthrie's Locality 1

Location: MS-1979, U-2; Sec. 6, T. 37 N., R. 87 W.

Horizon Description: Bright prominent brick red mudstone. Mottled red-brown-yellow at top, lateral to large, shoestring channel sandstone, abundant calcareous glaebules and pedotubules.

Material Preserved: Some associated mammal and lower vertebrate skeletal materials of single individuals. Well preserved mammal jaws abundant; eggshell, gastropod casts and silicified wood in small amounts.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect, quadrant sampling.

Comments: This fossiliferous horizon is the most fossiliferous of any horizon in the Lost Cabin Member; easily several thousand specimens known. Most mammals represented by at least 10 specimens. Jaws are fragments, reddish or orangish white with black, very dark brown or translucent gray enamel and white dentine. Teeth are often covered with calcareous glaebule mass which often infills alveoli of teeth lost prior to burial. Some remains show subaerial weathering. Abundant collections from this horizon in AMNH, CM and PU. Fossil materials can be easily recognized by their color.

UCM Loc. 79043: Sullivan Ranch Bed 4

Location: MS-1979, U-4; Sec. 6, T. 37 N., R. 87 W.

Horizon Description: Mottled red-gray mudstone, semi-resistant with calcareous glaebules; lateral to small shoestring channel sandstone.

Material Preserved: Primarily jaw and skull fragments of mammals and relatively complete turtle shells. Some associated bird bones. Isolated teeth somewhat common.

Paleoenvironment: Overbank/paleosol; lateral to shoestring channel.

Methods: Surface prospect.

Comments: This fossiliferous horizon is difficult to distinguish without careful scrutiny from UCM Loc. 79042. Some associated bones of single mammal individuals and well preserved turtles. A crushed skull of Heptodon ventorum with a dentary showing predepositional weathering. Jaw elements have gray or black, never white, bone and brown to black teeth. Calcareous glaebule mineral covering common. The unit can be traced directly into a shoestring channel sandstone that is channeled into the fossiliferous horizon of UCM Loc. 79042. Fossil vertebrates are rare in channel but become more common laterally.

UCM Loc. 79045: Jane's locality

Location: MS-1, U-8, Sec. 17, 20, T. 38 N., R. 87 W.

Horizon Description: Top of fine to medium quartz sandstone.

Material Preserved: Isolated teeth of mammals and lower vertebrates, one dentary of an anguid, some limb elements and turtle shell fragments.

Paleoenvironment: ?Braidplain.

Methods: Surface Prospect.

UCM Loc. 80061: Lightning Butte locality

Location: MS-1, U-56; SW ¼, Sec. 19, T.38 N., R. 87 W.

Horizon Description: Bioturbated gray mudstone with calcareous glaebules and pedotubules.

Material Preserved: Isolated teeth, jaws and limb elements of mammals; abundant amphibian bones (primarily anuran), snake vertebrae and anguid scutes. Rare turtle, crocodile and fish elements.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect, screen wash.

Comments: This fossiliferous horizon preserves an unusual assemblage of species, many of which are known only from this horizon. Rare mammals include *Mimoperadectes*?, sp. nov., Adapisoricidae, probably new, and cf. *Huerfanius* sp. The largest mammal recovered is cf. *Orohippus* sp. Abundant anuran fossils include all skeletal elements, probably of several species. This fossiliferous horizon undoubtedly preserves an assemblage of unique ecology. Bones are natural color and most teeth are translucent gray or light brown in color. This fossiliferous horizon has the potential for yielding well preserved material when excavated.

UCM Loc. 80062: Deadman Butte locality

Location: MS-20, U-2 (lower part); E ½ Sec. 22, T. 38 N., R. 87 W.

Horizon Description: Very fine grained, poorly sorted quartz arenite and mudstone. Most sand particles are very well rounded.

Material Preserved: Abundant isolated mammalian teeth and bone fragments ranging from *Lambdotherium* to *Pauromys* size. Turtle shell fragments and lizard remains common. Crocodilian elements rare and from very small individuals.

Paleoenvironment: Braidplain.

Methods: Surface prospect, screen wash.

Comments: Isolated mammalian teeth are extremely abundant, representing approximately 60 mammalian species. Only four jaw fragments containing teeth are known, all of which are identified as *Shoshonius cooperi*. Amphibian, lizard and turtle remains are common, whereas crocodile materials are rare and represented by small individuals. Pedogenic structures are not known from this locality. Fossils are randomly distributed (see Stucky and Krishtalka, 1982).

UCM Loc. 80063: Kevin's locality

Location: SE ¼, NW ¼, T. 37 N., R. 87 W.

Horizon Description: Light colored sandstone.

Material Preserved: Abundant turtle and crocodile, some large mammals. Small mammals rare.

Paleoenvironment: Fluvial system, presumably a stream channel.

Methods: Surface prospect.

Comments: Many bone and teeth elements have been abraided by stream transport. Jaw remains often show post-depositional distortion.

UCM Loc. 80064A-C: Sally's Catfish locality

Location: MS-1, Units 89-91; Sec. 30, T. 38 N., R. 87 W.

Horizon Description: Three fossiliferous horizons are recognized, only two of which preserve fossil vertebrates. UCM Loc. 80064-A is the lowermost horizon and is a claystone which is tabular and laterally extensive. UCM Loc. 80064-B is a carbonaceous shale that is conformable on UCM 80064-A. UCM 80064-C is a volcaniclastic paraconglomerate.

Material Preserved: UCM Loc. 80064-A preserves aquatic vertebrates. UCM Loc. 80064-B preserves plant remains and UCM Loc. 80064-C preserves rare teeth and limb fragments of mammals and turtle shell fragments.

Paleoenvironment: 80064-A is a probable lacustrine unit, 80064-B is probably paludal and 80064-C probably represents mudflow deposits.

Methods: Surface prospect, screen wash.

Comments: Catfish spines and small fish bones are extremely abundant in 80064-A. Fossils are randomly distributed within the unit.

UCM Loc. 80065: Rainbow Butte locality

Location: MS-3, Units 1, 2, 4, 5, 6, 8, 10, 11, 14, 15, 17; NE ¼, NW ¼, Sec. 19, T. 38 N., R. 87 W.

Horizon Description: Fossils recovered from eleven different horizons. See Measured Section 3 (p. 250).

Material Preserved: Primarily fossil vertebrates but also including some eggshell fragments and invertebrates.

Paleoenvironment: Most fossiliferous horizons are overbank/paleosol deposits, although some fossils occur in conglomerates and sandstones (Units 6 and 15) and are probably stream transported.

Methods: Surface prospect.

Comments: The Rainbow Butte locality preserves eleven distinct fossiliferous horizons in a vertical section of 90 ft. (27 m). Associated partial skeletons of a mesonychid, snake and crocodilia were collected. In Unit 7 an unusual abundance of amphibian remains of several individuals were recovered in a very small area. These amphibian bones may represent a predator accumulation.

UCM Loc. 80083: West Red Creek locality

Location: NE ¼, NW ¼, Sec. 18, T. 38 N., R. 87 W.

Horizon Description: Gray Claystone.

Material Preserved: Primarily isolated teeth and bones of mammals, turtles and crocodiles. Well preserved coprolites.

Paleoenvironment: Overbank deposit.

Methods: Surface prospect, screen wash.

Comments: This locality is probably the lowest in the Red Creek-Deadman Butte area. Although the fauna is small, the lack of *Lambdotherium* and any exotic taxa known from the *Palaeosyops borealis* zone suggests this locality may be Lysitean in age. Several limb elements of *Coryphodon* sp. may be from the same individual.

UCM Loc. 80088

Location: MS-18 and 19, U-16; Sec. 22, T. 38 N., R. 87 W.

Horizon Description: Mottled red-gray mudstone.

Material Preserved: Rare fossil mammals and turtle shell fragments.

Paleoenvironment: Paleosol?

Methods: Surface prospect.

UCM Loc. 80089

Location: MS-18 and 19, U-9; Sec. 22, T. 38 N., R. 87 W.

Horizon Description: Yellowish gray sandstone.

Material Preserved: Isolated teeth and bones of mammals.

Paleoenvironment: Braidplain or paleosol.

Methods: Surface prospect.

Comments: Highest occurrence of Lambdotherium in Deadman Butte sections. Probably correlates with UCM Loc. 80062.

UCM Loc. 80090

Location: MS-18 and 19, U-18; Sec. 22, T. 38 N., R. 87 W.

Horizon Description: Dark bluish-gray claystone.

Material Preserved: Large vertebrates, including associated partial skeleton of Coryphodon sp. and a crocodile.

Paleoenvironment: Unknown.

Comments: Lowest occurrence of Palaeosyops borealis.

UCM Loc. 80092

Location: Sec. 27, T. 38 N., R. 88 W.

Horizon Description: Red mottled mudstone at base of exposure.

Material Preserved: Isolated teeth and bones. One badly damaged partial skeleton of Coryphodon seen but not collected.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect.

UCM Loc. 81008: Viverravus locality

Location: MS-18 and 19, U-1A; Sec. 22, T. 38 N., R. 87 W.

Horizon Description: Gray sandstone with rhizoliths and burrows at top.

Material Preserved: Mostly isolated teeth and bone fragments of mammals, but some well preserved jaw materials. Few turtle or crocodile specimens.

Paleoenvironment: Braidplain.

Methods: Surface prospect, screen wash (Tylor 35).

Comments: Lowest locality in Deadman Butte sections. Teeth of the same individual of Phenacodus primaevus found in situ. Only some traces of the jaw bone remained, suggesting diagenetic dissolution of some bone material. In situ teeth and bone are randomly distributed in this fossiliferous horizon (see Stucky and Krishtalka, 1982).

UCM Loc. 81009

Location: MS-18 and 19, U-1B; Sec. 22, T. 38 N., R. 87 W.

Horizon Description: Gray mudstone.

Material Preserved: Isolated mammal teeth found as surface lag.

Paleoenvironment: Overbank.

Methods: Surface prospect.

UCM Loc. 81010: Palaeosyops jaw locality

Location: MS-17a, U-2; SW ¼, Sec. 27, T. 38 N., R. 87 W.

Horizon Description: Gray mudstone with calcareous glaebules.

Material Preserved: Extremely well preserved mammal jaw remains. Associated Palaeosyops borealis bones. Several hundred mammal and lizard bones, one turtle shell fragment. Calcareous fossil wood.

Paleoenvironment: Overbank/paleosol

Methods: Surface prospect.

<u>Comments</u>: Species known only from this locality include cf. <u>Washakius</u> sp. and cf. <u>Copelemur</u> sp. Probably the youngest fossiliferous horizon with abundant mammal remains in the northeastern exposures of the Wind River Formation.

UCM Loc. 81017

<u>Location</u>: MS-8, U-2; Sec. 36, T. 38 N., R. 87 W.

<u>Horizon Description</u>: Red mudstone.

<u>Material Preserved</u>: Single astragalus of <u>Palaeosyops</u> <u>borealis</u>.

UCM Loc. 81018

<u>Location</u>: MS-8, U-4; Sec. 36, T. 38 N., R. 88 W.

<u>Horizon Description</u>: Mottled gray mudstone.

<u>Material Preserved</u>: Partial skeletons of varanid (UCM collections) and <u>Palaeosyops</u> <u>borealis</u> (very fragmentary, CM collections).

UCM Loc. 81019: Kevin's <u>Notharctus</u> Bed

<u>Location</u>: MS-8, U-5; Sec. 36, T. 38 N., R. 88 W.

<u>Horizon Description</u>: Mottled red mudstone with calcareous pedotubules and glaebules.

<u>Material Preserved</u>: Associated skeletal elements of a crocodile and primate. Fairly abundant mammalian remains.

UCM Loc. 81022

<u>Location</u>: MS-9, U-1B; Sec. 6, T. 38 N., R. 87 W.

<u>Horizon Description</u>: Ant hill collection; gray mudstone.

<u>Material Preserved</u>: Isolated elements of vertebrates.

<u>Paleoenvironment</u>: Unknown.

<u>Methods</u>: Surface prospect, screen wash (Tylor 12).

<u>Comments</u>: Some bone elements found in situ lateral to ant hill.

UCM Loc. 81023

Location: MS-9, U-3; Sec. 6, T. 37 N., R. 87 W.

Horizon Description: Gray mudstone.

Material Preserved: Isolated bones of mammals. One oxyaenid skull and lower jaws in situ (CM collections).

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect, excavation.

UCM Loc. 81026

Location: MS-10, U-7; Sec. 6, T. 37 N., R. 87 W.

Horizon Description: Gray mudstone.

Material Preserved: Rare isolated bones. One partial skeleton of a carnivorous mammal (CM collections).

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect.

UCM Loc. 81027

Location: MS-10, U-8; Sec. 6, T. 37 N., R. 87 W.

Horizon Description: Ant hill in sandstone.

Material Preserved: Isolated teeth and bones of vertebrates.

Paleoenvironment: Fluvial system?

Methods: Surface prospect, screen wash (Tylor 12).

UCM Loc. 81028

Location: MS-11, U-1, Sec. 6, T. 37 N., R. 87 W.

Horizon Description: Gray mudstone.

Material Preserved: One isolated tooth of Trogosus sp.

UCM Loc. 81029: Buck Spring "dark red stratum" (Granger, 1910)

Location: MS-13, U-8, Sec. 15, T. 38 N., R. 89 W.

Horizon Description: Mottled purple mudstone with calcareous glaebules.

Material Preserved: Extremely abundant turtle and crocodile remains and isolated teeth and bones of mammals. Very few jaw remains. No associated skeletal elements of single individuals known.

Paleoenvironment: Overbank/paleosol?

Methods: Surface prospect.

Comments: This is the "dark red stratum" of Granger (1910) and "maroon shale" horizon of Guthrie (1971). Fairly abundant remains of Lambdotherium are known from this horizon. No specimens of Palaeosyops or Hyrachyus are known. Teeth are always black in color. Very few jaw remains are known. All that I have seen show post-depositional distortion.

UCM Loc. 81030

Location: MS-13, U-9; Sec. 15, T. 38 N., R. 89 W.

Horizon Description: Green apron-channel sandstone.

Material Preserved: One lower jaw of Phenacodus primaevus and turtle shell fragments.

Paleoenvironment: Stream channel deposit.

Methods: Surface prospect.

UCM Loc. 81031

Location: MS-13, U-10; Sec. 15, T. 38 N., R. 89 W.

Horizon Description: Red and gray banded mudstone.

Material Preserved: Fragmentary skull and lower jaw of Notharctus sp., cf. N. venticolus and jaws of mammals. Limb elements extremely rare.

Paleoenvironment: Unknown, but probably overbank deposit.

Methods: Surface prospect.

UCM Loc. 81032

Location: MS-13, U-11; Sec. 15, T. 38 N., R. 89 W.

Horizon Description: Red and gray banded mudstone.

Material Preserved: Fragmentary skeleton of Palaeictops multicuspis.

Paleoenvironment: Unknown, but probably overbank deposit.

Methods: Surface prospect.

UCM Loc. 81033

Location: MS-13, U-14; Sec. 15, T. 38 N., R. 89 W.

Horizon Description: Mottled red mudstone with calcareous glaebules and pedotubules.

Material Preserved: Numerous mammal postcrania. Associated pair of lower jaws of Coryphodon sp. Teeth and jaws are rare.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect, excavation.

Comments: The abundant postcrania but rare jaw remains are a paradox.

UCM Loc. 81034

Location: NE ¼, Sec. 17, T. 38 N., R. 89 W.

Horizon Description: Mottled red mudstone with calcareous glaebules.

Material Preserved: Isolated bones and teeth of vertebrates.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect.

UCM Loc. 81035

Location: NE ¼, Sec. 15, T. 38 N., R. 89 W.

Horizon Description: Mottled red mudstone with calcareous glaebules.

Material Preserved: Isolated bones, jaws and teeth of vertebrates.

Paleoenvironment: Overbank/paleosol.

Methods: Surface prospect.

UCM Loc. 81040: Croc Skull locality

Location: MS-21, U-8; Sec. 22, T. 38 N., R. 88 W.

Horizon Description: Gray mudstone.

Material Preserved: Isolated teeth and bones of vertebrates. One fragmentary skull of a small crocodile.

Paleoenvironment: Unknown.

Methods: Surface prospect.

Comments: Paleozoic clasts are common in conglomerates both above and below this horizon, suggesting that the sequence of strata in this area may be referrable to the Lysite Member of the Wind River Formation. No age assignment can be made on the basis of the fossil assemblage.

UCM Loc. 81047

Location: SW ¼, Sec. 31, T. 38 N., R. 87 W.

Horizon Description: Gray mudstone.

Material Preserved: Isolated teeth and bones of vertebrates.

Paleoenvironment: Overbank.

Methods: Surface prospect.

Comments: Correlates with UCM Loc. 81022 to 81023.

UCM Loc. 81048

Location: NW ¼, Sec. 12, T. 37 N., R. 88 W.

Horizon Description: Gray mudstone with calcareous glaebules and pedotubules.

Material Preserved: Associated skeletal elements of *Hyrachyus* sp., cf. *H. eximius*, teeth of *Palaeosyops borealis* and *Paramys*.

Paleoenvironment: Overbank/paleosol.

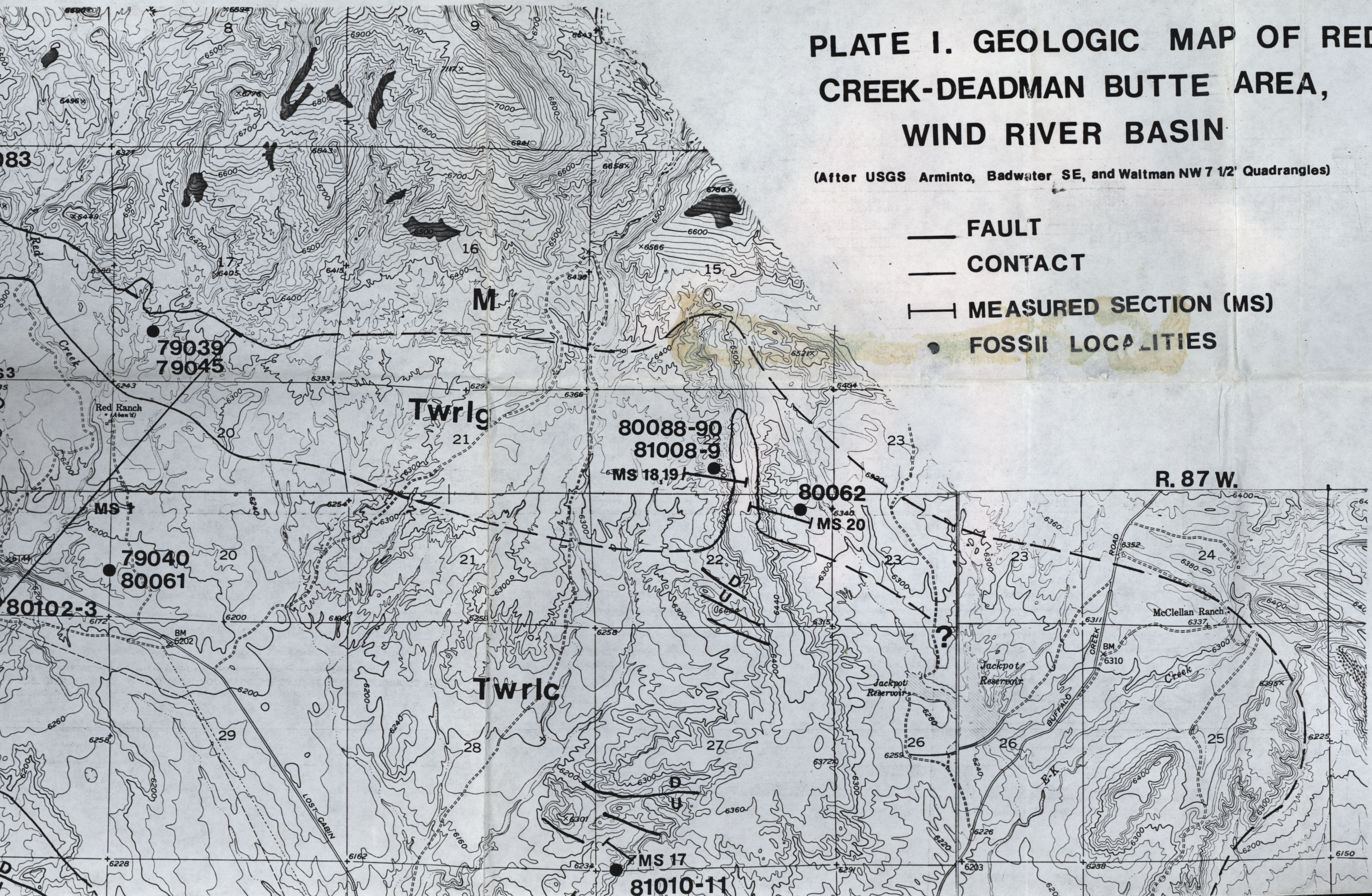
Methods: Surface prospect.

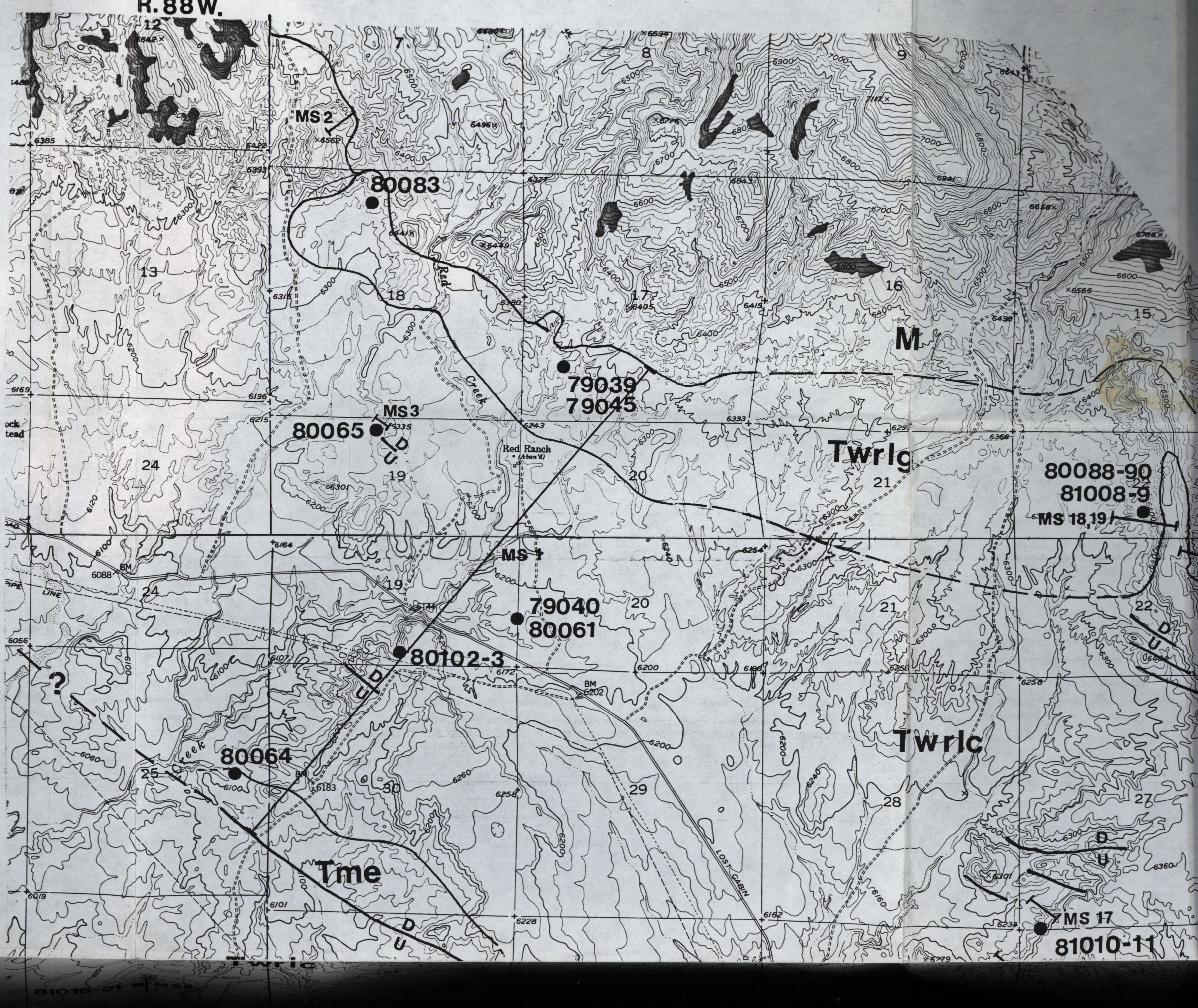
Comments: Correlates with UCM Loc. 79041.

PLATE I. GEOLOGIC MAP OF RED CREEK-DEADMAN BUTTE AREA, WIND RIVER BASIN

(After USGS Arminto, Badwater SE, and Waltman NW 7 1/2' Quadrangles)

— FAULT
— CONTACT
⊢⊣ MEASURED SECTION (MS)
• FOSSII LOCALITIES





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Red Ranch
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LOST CABIN
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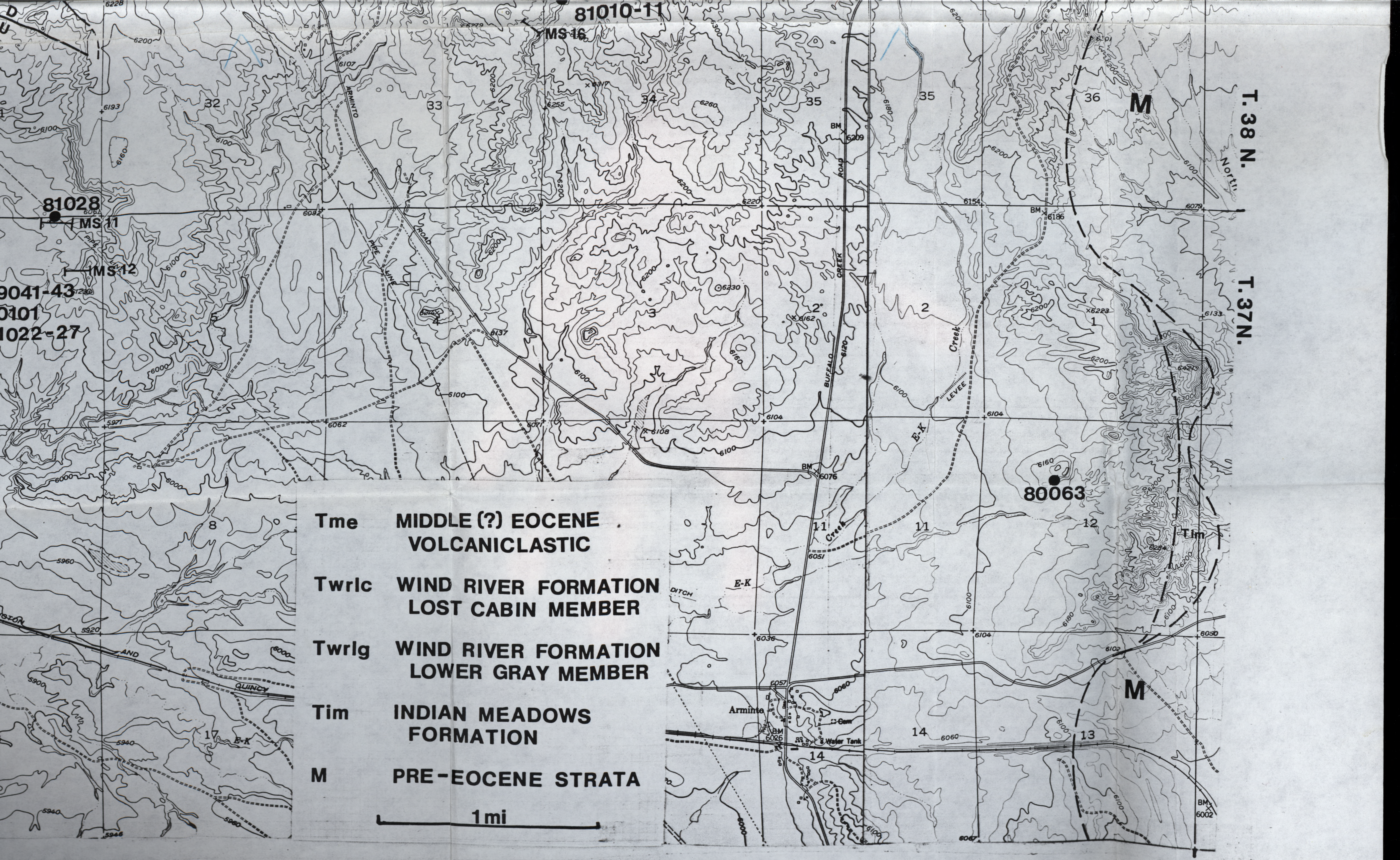
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9041-43
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ROAD
PIPE LINE
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Creek
LEVEE
E-K
DITCH
Arminto
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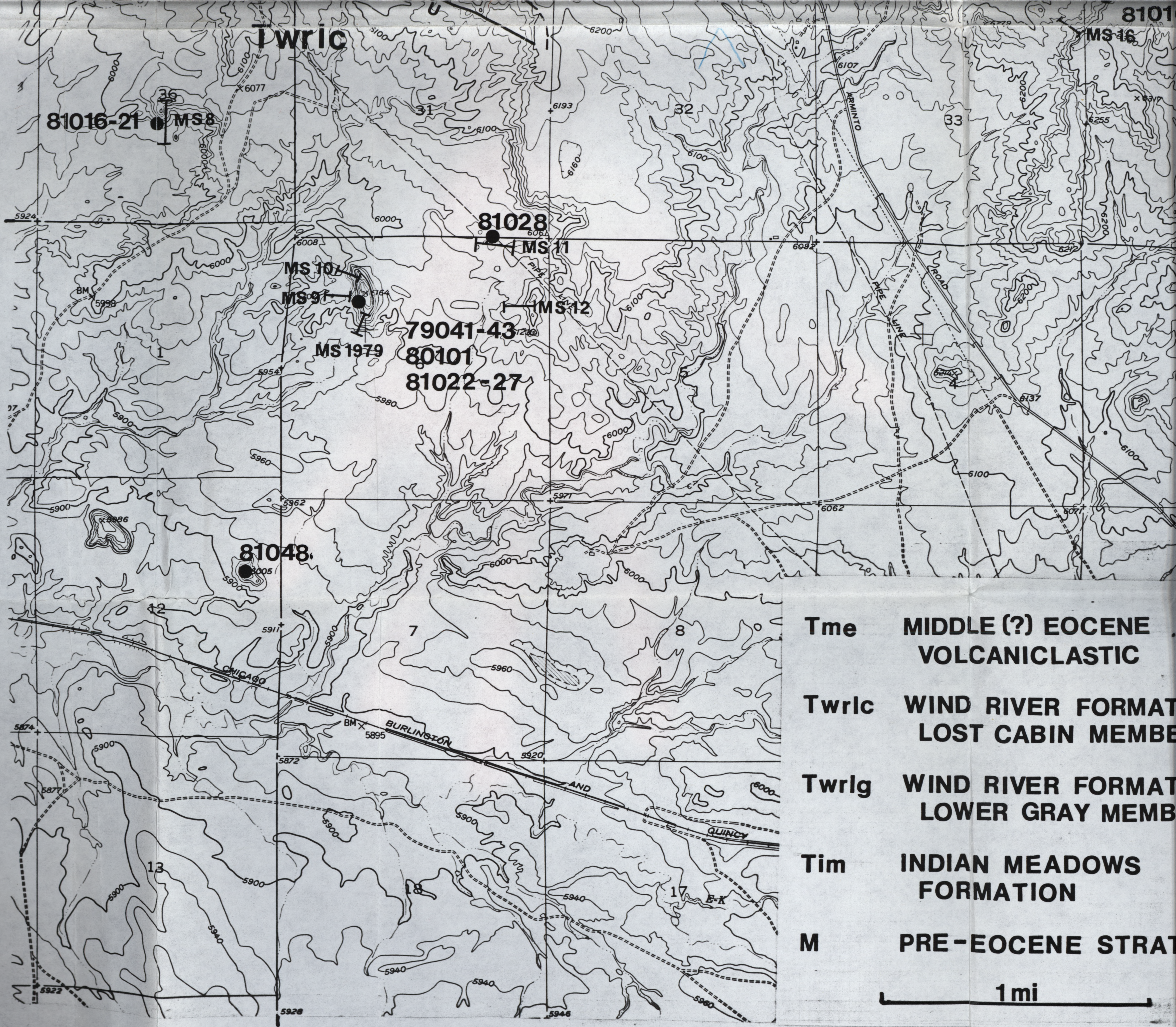
Twrlc
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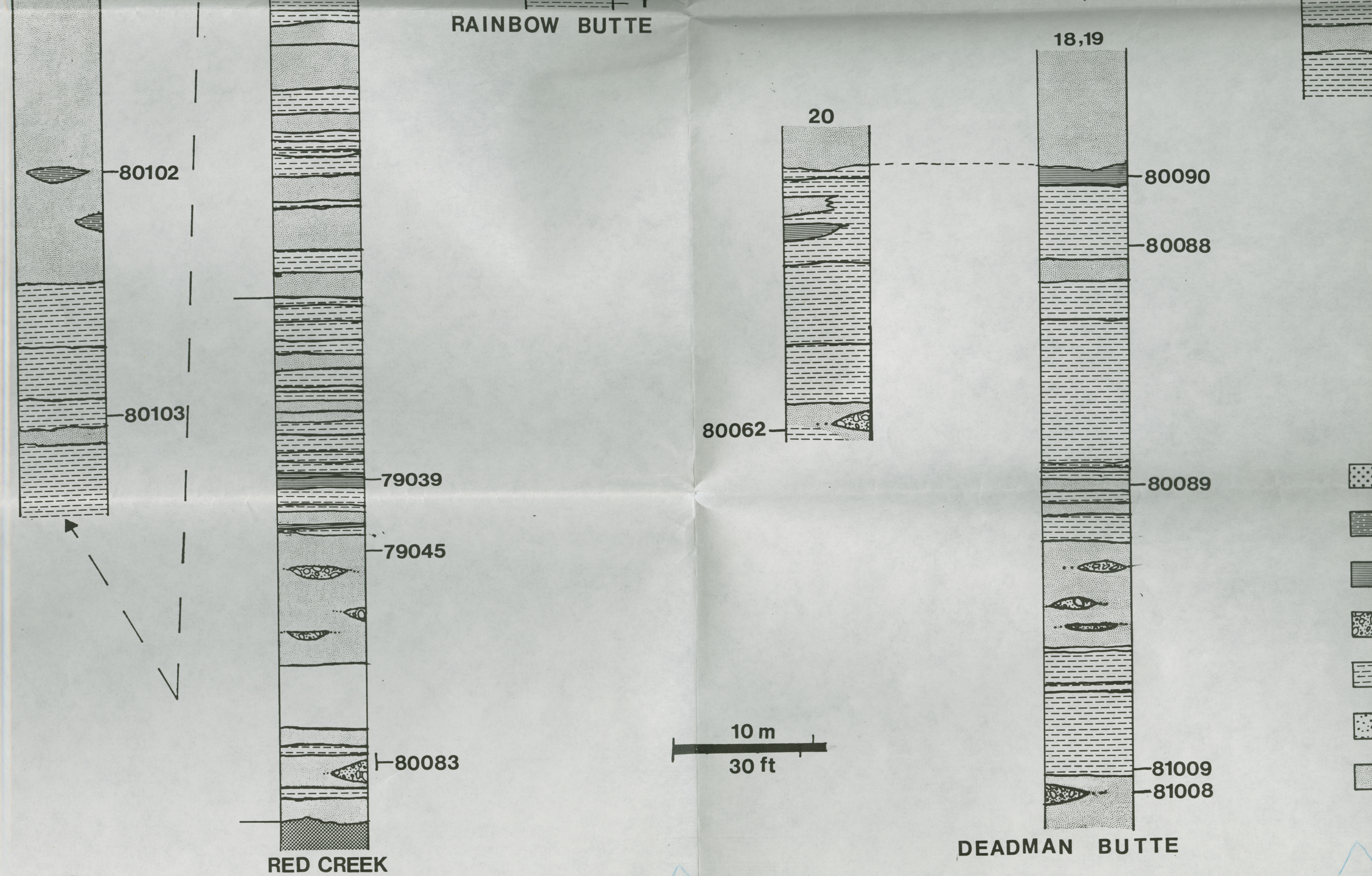

RAINBOW BUTTE
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DEADMAN BUTTE
10 m
30 ft

28

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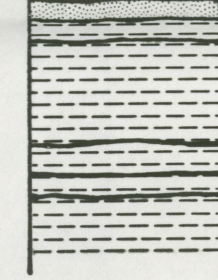
DAVIS RANCH



ONACEOUS SHALE

STONE

LOMERATE

TONE

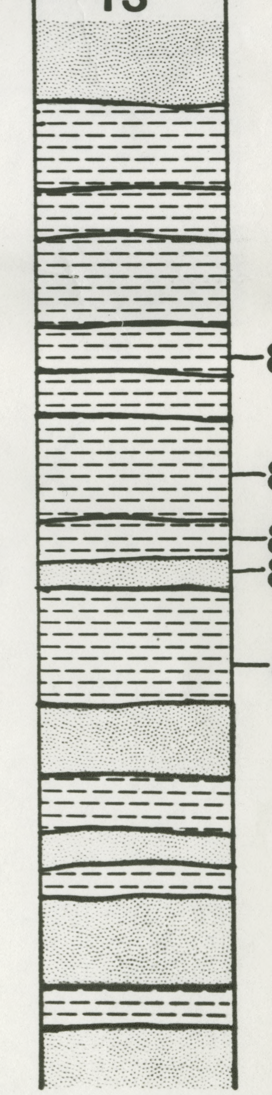
CONGLOMERATE

STONE

PLATE II. STRATIGRAPHIC CORRELATION

UPPER WIND RIVER FORMATION

13



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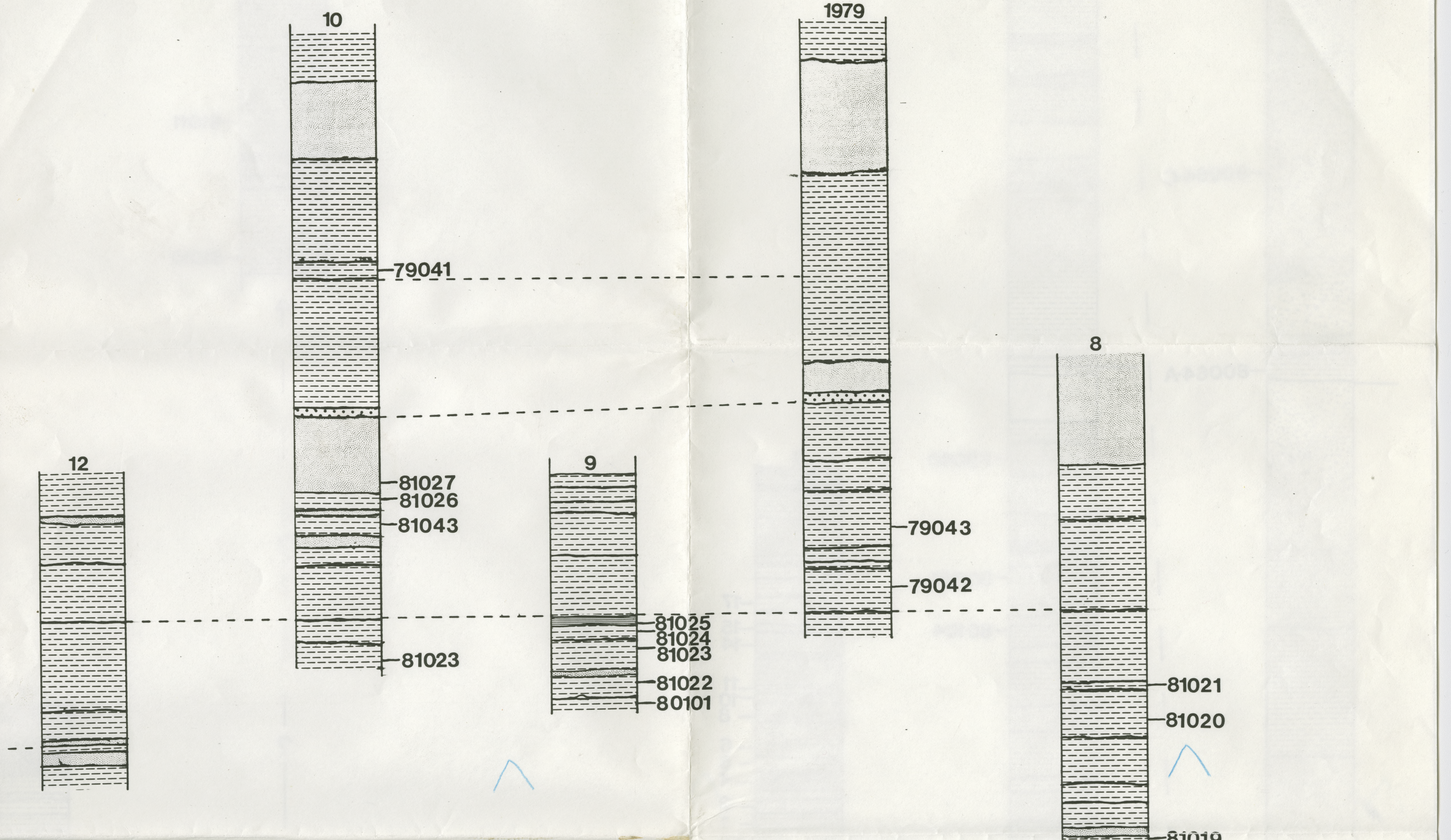
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DAVIS RANCH

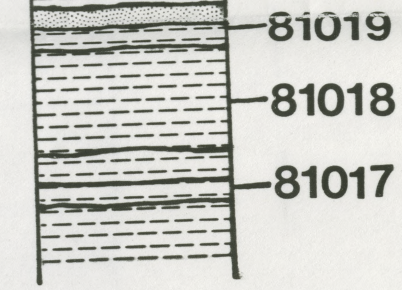


PLATE II. STRATIGRAPHIC CORRELATION
UPPER WIND RIVER FORMATION

ONACEOUS SHALE

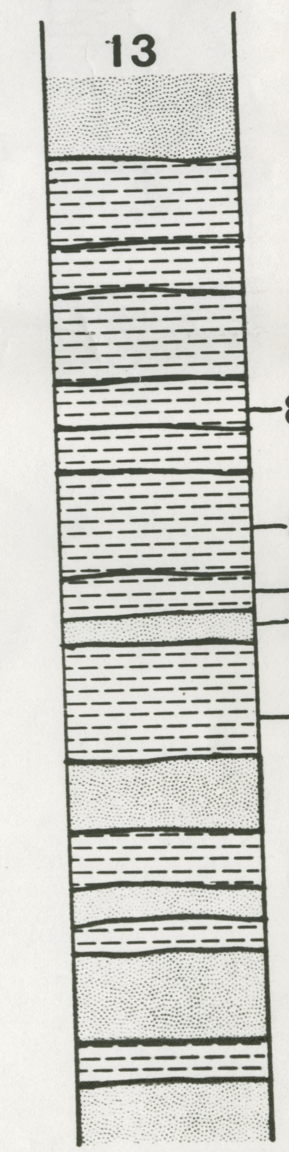
STONE

LOMERATE

TONE

CONGLOMERATE

STONE



BUCK SPRI